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The Victoria Falls Scheme.

WITHIN the last few weeks newspaper readers of all shades of opinion have been favoured with an extraordinary outburst of enthusiasm on the subject of the Victoria Falls. They have read more or less picturesque accounts of what one journal calls "the large and imaginative harnessing scheme which has long been crystallising in the mind of Sir Douglas Fox," a scheme that we are told will "stir the imagination of engineers all over the world."

Although the literary style and language of the various articles differ according to the brand of paper to which they were supplied, there is a wonderful family likeness among them.

Whether the daily Press have been bought wholesale, as many people think, or have merely been beguiled by the hypnotic influence of sanguine company promoters as the more charitable are willing to believe, we do not know and do not care. Our only reason for calling attention to the subject is to correct as far as possible some of the mischief that has already been done by innocent but injudicious sensation-mongers.

In the first place, let us see what is the general scope of the project, as stated in an official pamphlet recently issued by the British South African Company, who are the promoters of

the Victoria Falls Power Company, Ltd. According to that document, the main feature of the scheme is the generation by hydraulic power of electrical energy at the Victoria Falls and its transmission at 150,000 volts pressure to the Rand—a distance of about 700 miles. The initial installation of machinery proposed is only for the production of 50,000 h.-p.

As an integral part of the complete installation, the engineers have advised the erection on the Rand of a 24,000 h.-p. steam-driven generating station and a system of hydraulic accumulation patented by Mr. Wilson Fox, the erstwhile journalist "who is the real originator, organiser, and promoter of the Victoria Falls Power Scheme."

The object of the accumulator system is to pump water into high-level reservoirs during times of low demand for power, and to use it for the reproduction of power when required, the capacity of the reservoirs to be adequate for a twelve hours' supply. To do this, necessarily involves additional water turbines and generating plant at the Rand end of the transmission line.

The object of the steam-driven plant is to act as a stand-by in case of temporary interruption of current from the Falls.

The foregoing is a brief outline of the scheme, for the realisation of which the promoters want the sum of three million pounds.

Quite apart from technical difficulties, it is obvious that this is altogether too large a capital in view of the small output of the plant and the low price at which current will have to be offered to mine owners and works proprietors on the Rand. There are good reasons also for believing that the operating costs and maintenance charges involved in the proposed installations will be far more serious than the promoters seem to imagine.

While fully agreeing with those who think it desirable to utilise the enormous possibilities of Victoria Falls for the generation of electricity, we cannot see in the present scheme any promise of commercial success.

At present, a tentative suggestion is made to the effect that the company may ultimately adopt three-phase transmission at the pressure of 150,000 volts and a frequency of 12·5 periods, the conductors being carried on steel towers about 60 ft. high, and spaced 1,000 ft. apart. So far no attempt has been made to transmit electrical energy for a greater distance than 400 miles, or at a greater pressure than about 80,000 volts. Consequently, no one can speak positively as to the probable behaviour of this transmission line, and it is by no means certain that the losses can be limited to 25 per cent. as estimated. No one is in a position to speak with any certainty about the difficulties that may and probably will arise in connection with insulators, or the troubles that may be caused by the frequent and violent thunderstorms that occur on the Rand during the rainy season.

Practical experience in the United States, with comparatively short transmission lines, goes to show that lightning is a very fertile cause of interference with continuity of supply, and the application of arrestors—as proposed by the Victoria Falls Power Co.—does not seem to be attended with particularly satisfactory results. As for the air loss, we know that it is very considerable even for 40,000 volts, and what it would be for 150,000 volts, we should not like to conjecture.

One other probable cause of interruptions is to be found in the wild and unsettled nature of the country to be traversed, a view which seems to be fully shared by the company, if we may judge by the importance they attach to the double stand-by represented by the accumulator system and the steam-driven generating station.

From some biographical notes issued in pamphlet form by the Victoria Falls Power Co., we learn that Mr. Wilson Fox, the inventor of the hydraulic storage system which is to "revolutionise the practice of long-distance transmission," is a fine speaker on political and commercial subjects, and has an unusual hold over public meetings.

Judging by the acceptance of his wonderful system, we are inclined to think that his eloquence and "unusual hold" must have been exercised on the engineers responsible for the technical details of the general project. Mr. Wilson Fox's idea, described in his own words, is as follows:—"We shall, whenever there is spare power available, use it to pump water into a reservoir at the top of a high hill, where it will constitute a reserve supply of energy. We can then allow it to run down again through pipes to the bottom of the hill, and we shall thus be able to constitute at pleasure an artificial waterfall, and by its use regenerate power." We do not know definitely what is to be the elevation of the high hill above the bottom, where we assume a second reservoir would be constructed for the purpose of avoiding the waste of precious water. It is stated, however, that the difference of level will be 600 ft., and it will at once be seen that the current consumed in pumping operations would be a very heavy item. Reservoir construction is most costly work, and taking into account the initial outlay on land, pumping plant and electrical equipment, as well as management and maintenance charges, it is impossible to avoid the conclusion that the hydraulic storage system would be a very extravagant way of providing a temporary stop-gap in case of breakdown.

Even with a free water supply, the loss by evaporation and losses of efficiency in the pumping and generating plant would eat up a very large proportion of the available power, and we are sure that any remaining advantage would be absorbed by the cost of management, and other unavoidable charges.

Regarded as a stand-by, the steam-driven generating station would also be a most costly expedient. As it is claimed that the hydraulic accumulator system would make it unnecessary to keep the boiler plant under steam, there would be no work for the reserve station staff, although we presume that shareholders would have to pay their salaries and wages. If, on the other hand, the station were left without a staff, then it could not be of service in the event of breakdowns in the transmission line.

As a matter of fact, however, the company do not really propose to build the steam-driven power house as a reserve station at all. Their real object is to employ it as a means of securing customers among mineowners who would otherwise have to lay down generating plant of their own. After a connection has been secured, and not until then, will the larger project be seriously entertained. If that undertaking ever comes to be realised, the steam station will be practically useless except as an extravagant and inadequate reserve plant.

So, at last, we find this ambitious project dwindles down to the very modest scheme for erecting a small generating station on the Rand, and all the tall talk that has gone the round of the daily Press is little more than a lever to move the feelings of the British public, and, of course, to open their purse strings.

We would not for a moment say a word to discourage the establishment of a British generating station on any likely site, but we are sorry to say that the so-called Victoria Falls scheme for building a power house on the Rand turns out to be simply a device for giving a large order to the Allgemeine Elektricitats Gesellschaft of Berlin, by whom "the construction of a 24,000 h.-p. steam-driven station on the Rand, in a suitable position in the neighbourhood of Johannesburg, is to be immediately proceeded with." This extract from the official pamphlet of the British South Africa Company is sufficiently explicit as to the manner in which the company are trying to excite British patriotism for the purpose of raising money to benefit German manufacturers.

Modern Train-Speed Indicators.

By CHAS. R. KING.

INDICATORS for revealing the speed of railway trains are of early origin, dating almost from the growth of railways. In Switzerland, on the Basel-Olten line, fixed tachometers were installed in 1855, and worked by means of rail contacts and electric current. Portable tachometers for indicating the train speed to the men on the locomotive have exercised the minds of many inventors since that period, but, of those which have been constructed on different systems previous to 1885, very few, if any, have survived the rude test of every day service. Their utility has been intermittent. Their employment not being, in their own time, a positive necessity such as to render them indispensable, there has been no powerful incentive for their continuation. But speeds, like boiler pressures, have increased and, without measuring gauges, the potential danger of the one has become to be almost as much feared as the other. In the early future an engine without a speed indicator will be considered as potent in danger as its boiler without a pressure-gauge, or as a train without a continuous brake. A mass weighing up to 600 tons, moving at from 70 to 80 miles per hour, is a force that must be properly gauged, equally as a boiler of 240 lbs. pressure. Nearly all railway companies of the Continent (including a few in France), long since recognised the necessity for speed indicators or tachometers combined with speed recorders or tachographs. The rule-of-thumb method of estimating speed as practised by the enginemen was considered dangerous—as much so as feeling the lever of a safety valve to guess at the boiler pressure without a proper steam-gauge. There was no order, and no system, without a steam-gauge; and in case of accident there was no undeniable proof that the speed was within admitted limits, nor any proof that those limits had been exceeded. The rational and scientific remedy was the (compulsory) universal adoption of automatic recording speed indicators. Their use was of the greatest importance for the safety of railway passengers while, in second line, they permitted of the fullest control in the traffic operation. The timing of trains over every section of a line had to be adhered to, otherwise the velogram, or recording diagram told on the delinquent. If one man could get his train quickly over a very difficult and trying "stretch" under adverse meteorological circumstances others also would have to do it—and did. The average speed was thus increased, the traffic potential of the line developed, and the necessity to gallop down declivities was obviated—and forbidden. The wonderful achievements of express trains in running down steep gradients by the sole force of gravity, which so delight the "speediacs" in countries where there is practically no limit to the velocity, became unknown.

Why the countries of East-Central Europe should have been foremost in the general adoption of speed-meters is readily understood from the fact that, while their tracks were the lightest, they had the greatest constructive gauges of all Europe, and their tracks carried engines and cars of a weight and size unknown in North-Western Europe and England.

Step by step, Western Europe has followed up these advances of the East, and to-day we face the unavoidable necessity of also adopting some of those safeguards which our predecessors in the practice of heavy transport had

found indispensable for their own security and for the public safety. The chaos that has been revealed by our Board of Trade inquests into railway accidents has a remedy. Those inquests show that the restrictions on train speeds are daily ignored by the enginemen, and even by the whole staff; and when attended by good luck, these infringements of speed rules have developed into accepted practice—until a disaster has finally pointed out the transgression. The remedy, in the form of recording speed-indicators, would entail an expense not hitherto foreseen in the days of lighter trains, smaller traffic and lower speeds; but this expense would be fractional as compared with the loss, intrinsic and moral, due to those accidents preventable by means of recording speed gauges, such as, for instance, was undeniably the case at Salisbury, as elsewhere, in 1906. The expense will scarcely deter English Companies from adopting these safeguarding appliances; for, without any greater pressure than that due to competition, British railways have never spared expense in the matter of fast, comfortable and clean railway travelling. Our express trains with third classes, and dining and sleeping cars, are models of excellence as compared with the extra-special first-class *trains-de-luxe* of the Continent, notwithstanding their exorbitant fares; and with wooden coach frames and wood-webbed wheels the railways of the United Kingdom provide their passengers with a luxurious easy riding unknown on the Continent, and even ignored by English passengers at home. But safety in travelling can be yet improved upon even in England.

In view of the imminent importance of recording speed indicators in the United Kingdom the following descriptions are given of the tachographs now employed on the Continent. These instruments, like some electrical machines, are necessarily complex. It may be said that there does not exist any machine so fine and delicate, comprised in such a small compass and able to resist such rough jars, as the recording speed-indicator. Even electrical instruments appear as rough machines by the side of tachographs. The study of these very beautiful speed measuring instruments is unquestionably stimulating and instructive in the highest degree; in their theory and calculation the mathematician finds a great store of intellectual work; in their mechanical combinations the engineer derives many suggestive ideas for like applications, and in the solving of problems, from the diagrams produced, the running and traffic departments of railways as also, in a general way, the designers of locomotives, find a study of the most interesting and valuable nature.

In France, where, as in England, high speeds are run by a certain number of "crack" trains (of a "limited" description) it has lately been found desirable to render the use of tachographs compulsory on every passenger locomotive, notwithstanding that, even on the easy, straight lines of the Nord, the outside speed-limit is, by law, only 75 miles per hour, while other French railways are often limited to 57 miles per hour. But it will be understood, that it is not only high speeds that are provocative of accident, for there are certain conditions of repair in the permanent way or engineering works which, in England, as elsewhere, make speeds of thirty and even twenty miles per hour dangerous, and it is here that the tachograph reveals how far the enginemen have obeyed permanent or temporary notices as to speed-limits. Of modern speed measuring instruments for locomotives, a few of the best-known and most reliable tachographs have been selected for general description here, and in each case these are machines already extensively employed upon European railways, and of proved reliability and durability. In passing, we cannot but recognise the great ingenuity embodied in many systems of speed indicators, some of which strike the least practical of minds as being quite useless for the rough service of a locomotive engine.

We have, for instance, the recent German invention of Frederick Lux, which in principle depends upon the vibration transmitted to some fifty flat steel watch springs, of graduated lengths, by means of a polarized electro-magnet wired to an alternating current generator mounted on one of the engine driving wheels, the period of vibration (depending upon the speed of the engine) in each spring being made to correspond to all the rates of motion.

The impulse given to a column of water by means of revolving beaters, or a turbine, has often been invoked by inventors. Most readers will recall the "Stroudley" indicator of the London, Brighton and South Coast Railway in this connection, and also the recent device of the French P.L.M. Railways. Such instruments are termed "direct-acting," and belong to the same category as those apparatus where the masses displaced under the influence of speed are solid ones and dependent upon centrifugal force either in connection with vertically-acting weights or with one or several springs, the combination serving to measure the angular speed of an axis turning proportionately to the ratio of movement of the train. Tachometers and tachographs designed upon this principle have been numerous, including the instruments by Klose, Schaefer and Budenberg, Dr. Horn, Brown, Aumund, Dr. Braun, Butler. These direct-action speed-meters indicate the speed instantly and uninterruptedly, and not intermittently as in all modern instruments now in use on railways. There are also a few instruments which likewise register instantly (or almost so) and continuously, but in which the angular speed of a shaft or disc is measured, not directly as in the preceding category, but in function of the half-diameter (presumed to be variable) of the revolving disc—the construction being based upon the principle of the comparison of two speeds: the one known, the other unknown. Examples of this category are the speed-recorders of Amsler and of Schmassmann. In these two instruments the speed of the engine wheels is measured by a differential gear and compared with the constant speed of a clockwork movement. Such recorders, though extremely ingenious, are necessarily somewhat complicated. The Alfred Amsler apparatus is only employed in connection with other instruments, as, for instance, in the new tractometer cars of the Paris-Orleans and Belgian and Italian State Railways; while the "Schmassmann," although in use on some Continental railways, presents greater interest for street vehicles where the almost momentary registration of the speed is of more consequence than in heavy railway trains, the mass of which is not susceptible to the same sudden variations of velocity. In general all the foregoing instruments record the speeds in unbroken lines by means of pencil, metallic style, or aniline ink.

The third category of tachographs now to be mentioned are termed "totalisers" from the fact that they sum up and average the speed during each consecutive period of from three to six seconds—according to the setting of the apparatus—which varies in the different instruments. Examples of these are the "Kraemer," "Brettmann," "Hausshaelter," "Hasler" and "Flaman" recorders. The three last-named instruments are the most extensively employed of all modern tachographs, and will therefore be described in some detail. The principle upon which they are constructed is the positive gearing of the velocity and time mechanisms, and by which the amplitude of an angular movement is measured during a unit of time or of distance, the speed measure being renewed incessantly in periods of every few seconds. In these the movements effected are the absolute consequence of this particular form of construction, termed chrono-geared (*i.e.* having conjugated gearing) and are not movements which would be sought in an ideal apparatus for the instantaneous measurement of the angular velocity: which ideal does not exist, as the results obtained from those machines based upon centrifugal force are dependent

upon periodic empirical regulations which cannot be always trusted. At this stage it is desirable to briefly compare the operation of the three categories of instrument for the measurement of angular velocity.

The indications furnished by instruments based upon the action of centrifugal force are nearly always dependent upon a spring or springs whose tension is regulated experimentally during the construction, but which tension, as will be readily conceived, is subject to invisible modifications in the course of service and thus to lead to erroneous measurements; and in order to maintain instruments of this type in condition for giving results of approximate accuracy it is absolutely necessary to adjust them periodically by means of empirical tests. Apart from this constant inconvenience instruments of this type have a rather small range, or zone, wherein the records have an equal accuracy, and beyond which the results are either inaccurate or nil. The speed-bands upon which the records are inscribed have unequal longitudinal divisions (see Fig. 6), which increase in width up to, say, 30 kilometres per hour, and then decrease in width beyond, say, 70 kilometres per hour, and so in proportion to the average speeds for which the instrument is designed. In order to avoid, as far as possible, the influences of shocks of the locomotive upon the pieces in movement it is usual to endow the rotating parts of such instruments with a very rapid turning speed which therefore requires a transmission gear of high development subject to derangement. Despite this rapid speed of rotation the speed diagrams show an almost continual oscillation of the recording pen due to shocks, &c., so that the speed-line is often thick with this amplitude of close vertical movements, and in the centre of which must, of course, lie the real momentary train-speed. It may be surmised here that the needle of the tachometer or indicator vibrates with a corresponding amplitude; on the contrary, so far at least as the writer has been able to observe the "Klose" tachograph while in service, the indicator hand of this instrument has a fixity equal to that of any recent tachographs. The "Klose" recorder is the principal instrument of the centrifugal type, and is used in Switzerland and Baden. It is the system adopted by the Gotthardbahn and is kept in repair and regulated at the company's works at Bellinzona in Italian Switzerland. The accompanying illustration Fig. 1 shows its general form, and Figs. 2—5 its means of application to locomotives. The means of transmission in use for this tachograph are very varied, this being by the usual crank on the coupling rod, or one of its pins; by chain, or by a roller on the tire of the wheel. Of the latter, which measures the actual circumference of the tire *under all conditions of wear*—new or old—it has been sometimes said that the high speed at which the roller turns is liable to cause it rapid wear and so produce considerable

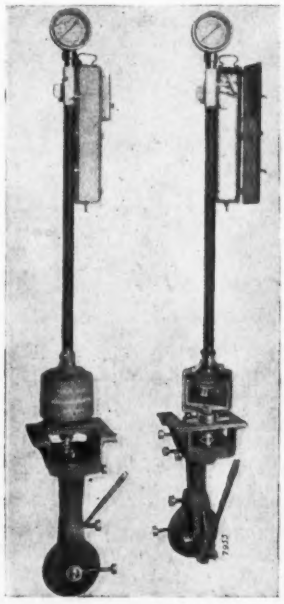


FIG. 1.—GENERAL VIEW OF "KLOSE" TACHOGRAPH WITH CRANK TRANSMISSION.

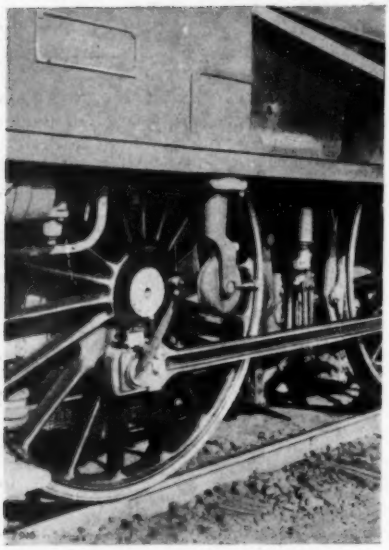


FIG. 2.—"KLOSE" TACHOGRAPH. CRANK TRANSMISSION.

inaccuracy in the records. On the other hand, it may be remarked that this cheap iron roller could be replaced very frequently and always of such diameter to make precisely the same number of turns for every revolution of the driving wheels, no matter whatever modification had occurred in the diameter of the driving tires.

The "Klose" indicator when maintained in perfect condition is a reliable guide for the engine men—as it needs to be on the steep inclines of the Alps — and the records it furnishes answer for all general purposes of speed control. It indicates and records the actual *momentary* speed of the train, which those instruments based upon other principles do not do. But, as the speed of trains varies only insignificantly in intervals of one or three seconds, other types of tachograph giving slower indications but of more constant reliability are now preferred everywhere.

The tachographs based upon the comparison of a known to an unknown speed are a compromise between the centrifugal and the positive-geared types. In these (of the differential type) the clockwork movement usually employed for the known speed is practically limited to 1·5 second on average. To establish the due comparison between the two speeds — known and unknown — it is necessary to take for basis a period of time of sufficient length to ensure an accurate result, and the consequence is that the speed indicated is not the actual velocity of a given moment despite the claim usually made in the affirmative. In a lessened degree they share the disadvantages of the direct-acting speed indicators as also of the totalisers or intermittent indicators.

The modern speed-indicators are all of the conjugated type. Foremost of these—so far at least—is the instrument invented by Hugo Hausshaelter, of Dresden, and made by Seidel and Naumann, A.G., of that city—which is the place of origin of several other

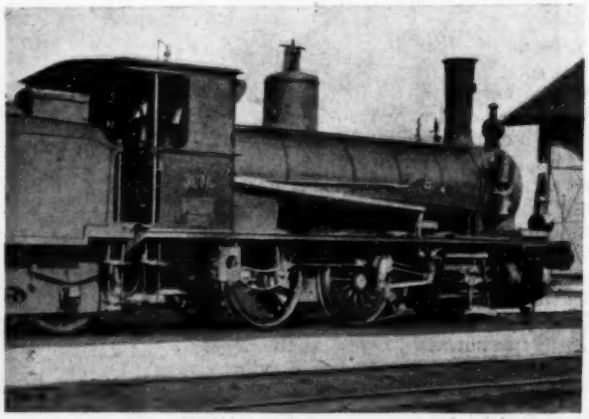


FIG. 3.—"KLOSE" TACHOGRAPH TRANSMISSION BY CHAIN

tachometers, in common with typewriters, sewing machines and such like fine mechanical work. It was introduced about the year 1885, and since that time has been adopted generally by nearly all railways of the European continent excepting the French. From a rough calculation there would be about 12,000 of these instruments supplied to various countries, including about 800 to France.

The "Hausshaelter" recording speed-indicator measures the speed by the distance covered on rail during each consecutive period of twelve seconds, in which time a cylindrical weight is lifted from the position it occupies in a state of rest to a height proportionate to the average speed of rotation of the wheel from which the movement is derived. This weight is, in consequence, the most essential part of the apparatus. The action of the mechanism will be explained subsequently.

The "Hasler" recorder, which closely resembles in form the "Hausshaelter," was designed as an improvement upon this latter and will also be described in detail later.

In all the instruments so far referred to, the paper bands on which the diagrams are inscribed are unrolled under the marker by clockwork, and are therefore scaled on a time basis although the distances covered on the rail are also indicated, in fractions of kilometers, by means of perforations, on the edges of the paper band, spaced irregularly and decreasing in their spacing as the speed becomes greater. Although in these diagrams the timing is perfect from end to end of a run there exists one important inconvenience with regard to the exact distances traversed up to any moment or, in other words, to determine with absolute certainty the speed at any given point. As a matter of fact the kilometric point or punctuations do not, as a rule, coincide with the starting point of the speed diagram, and when, in ulterior investigations on the diagram, it is required to know (as often occurs in daily routine) the speed at which the engine has passed a certain point upon the line it is found to be extremely difficult, if not impossible, to determine with absolute certainty the position of

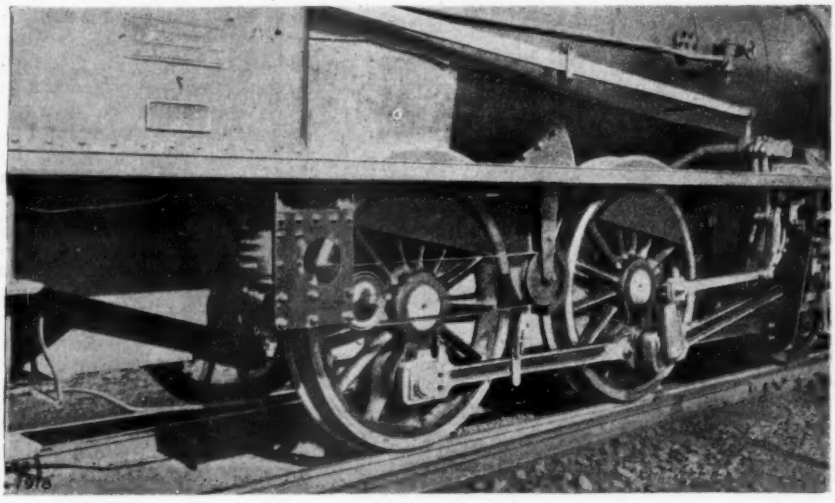


FIG. 4.—"KLOSE" TACHOGRAPH. TRANSMISSION FROM COUPLING ROD THROUGH BELT AND PULLEYS.

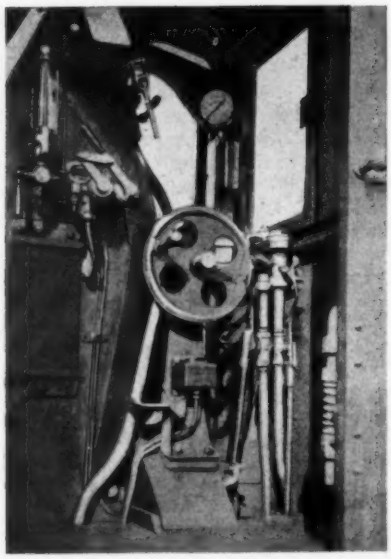


FIG. 5.—"KLOSE" TACHOGRAPH. INDICATOR MOUNTED IN CAB.

(The dial is placed horizontally near the reversing wheel.)

that point upon the speed-band, this point being a function of that of the start. The result obtainable is only approximate—within from six to seven hundred yards, and this, experience has shown, is not sufficiently close where the investigation has connection with some incident revealed by the diagram, as slipping, &c., or with some accident to the train. Moreover, the tension on the paper and an imperfect order of the punctuating mechanism may sometimes add to the difficulty mentioned.

These limitations of the time-operated speed band led to the introduction of the "Flaman" instrument, in which the paper band is unwound under the marking styles in exact proportion to the distance covered on the rail. This most recent of modern tachographs depends in principle, for the measurement of the angular velocity, upon the displacement of a ratchet wheel (actuated by a pawl deriving its movement from the driving wheels) during each consecutive period of 4·8 seconds; in this time the ratchet wheel describes a greater or less angle according to the speed of the engine. The mechanism and its working will be described subsequently.

The diagrams, the product of the instruments, are of necessity the one chief point of interest by reason of the store of information they contain; and, all things being equal, that instrument producing a diagram replete with most data serving in the clearest and most lisible manner as basis for ulterior investigations—whether for control or for computations—that instrument is the one having the greatest advantages for the running departments of a railway. All the centrifugal type and also the differential type machines trace the diagram in a continuous unbroken line which is very clear when, as in the "Klose," aniline ink is employed; the positive-geared instruments punch the speed line in a series of holes, excepting only the "Flaman," which traces a speed line by means of a soft brass style, in a series of "steps" as shown in the examples reproduced. All reproductions, even full-sized, of the "Flaman" diagrams are very coarse compared with the originals in which the speed line is very fine and delicate, although keen when viewed by reflection at a certain angle. With the naked eye it is possible in the "Flaman" diagrams to notice that those lines representing an unwavering continuity of the same speed are divided their whole length by minute strokes always of a uniform spacing corresponding in length to the shortest steps in the speed line. These strokes have a height of about half the thickness of the fine speed line, and occasionally attain a height equal to one of the "steps" in the speed line. The longer strokes, which are apparently parasitical to the speed line, in no way alter the course of the latter, but appear to incidentally furnish an indication of engine shocks occurring at various points on the line. In other styles of diagrams with perforated lines such shocks might confuse

slightly the real speed line, but in the stepped speed line of the "Flaman" instrument they leave the speed line unbroken. In this instrument the time line occupies a separate part of the paper band. The exactitude of the latter measure is assured by the regular beat of the clockwork escapement, which is so disposed as to remain uninfluenced by the oftentimes violent shocks upon a road in indifferent condition. The relatively heavy weight of the escapement wheel and the frequency of its beats (1-5 second) as well as the constancy of the motive effort, due to the great length of the barrel springs and their constant automatic rewinding, all contribute to an extreme regularity of its time and speed movements.

We will now compiete the examination of the mechanical details of the three speed recorders which are accepted as the best instruments in present-day use, that is the "Hausshaelter," "Hasler," and "Flaman."

The "Hausshaelter" is shown by the drawings Figs. 7 to 18, and the Fig. 19 is a facsimile of a speed band made by it on an express locomotive of the Italian State Railways whilst accompanied by the writer and other engineers.

The barrel or weight, *B* is raised along the shaft *E*, but being retained by feather key is obliged to turn with the shaft. The barrel is cut with circumferential grooves shown in the detailed plan Fig. 10 at *b*. In these grooves gear the spur teeth of the pinion *g*, cut upon the spindle *C* (Fig. 10). The grooves *b* (Fig. 10) are cut away, parallel to the shaft *E*, at the portion of circumference marked between *a* and *b*. By this means the barrel *B* is raised to a height which is always proportional to the speed of the main driving spindle *A* (Fig. 8) and therefore to the rate of movement of the locomotive; but, whatever be this height, the complete revolution of the barrel *B*, once in every twelve seconds, causes the teeth *g* to ungear from it at the point *a* (Fig. 12), so that the barrel falls to the bottom, when

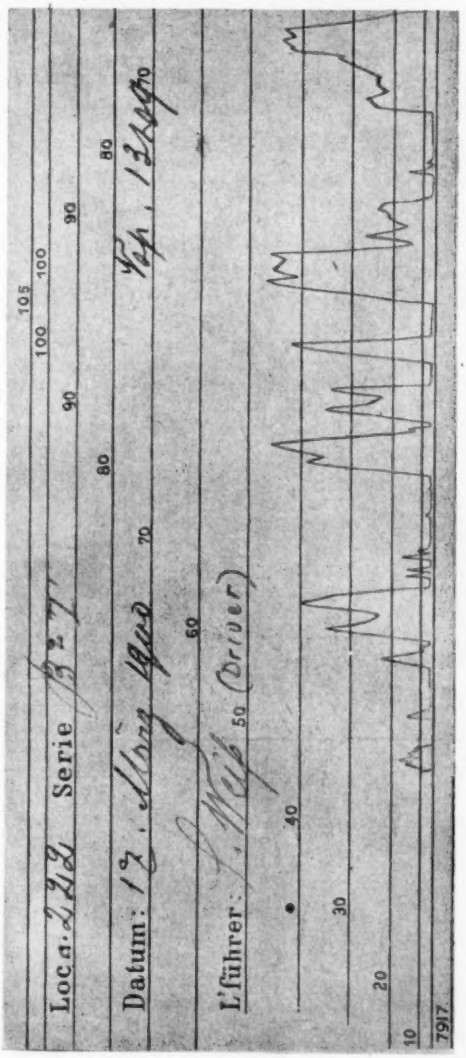


FIG. 6.—"KLOSE" DIAGRAM. FULL SIZE.

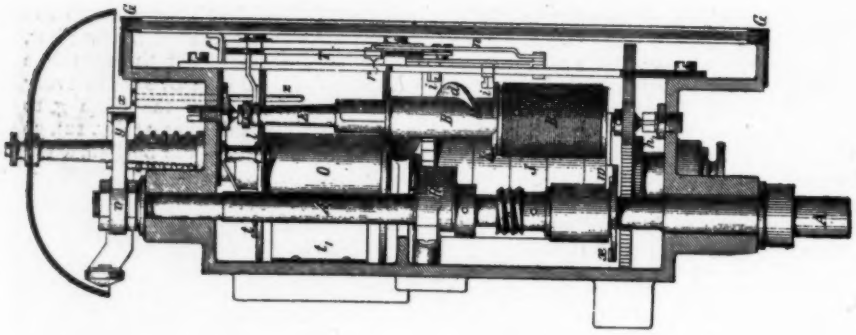


FIG. 8.

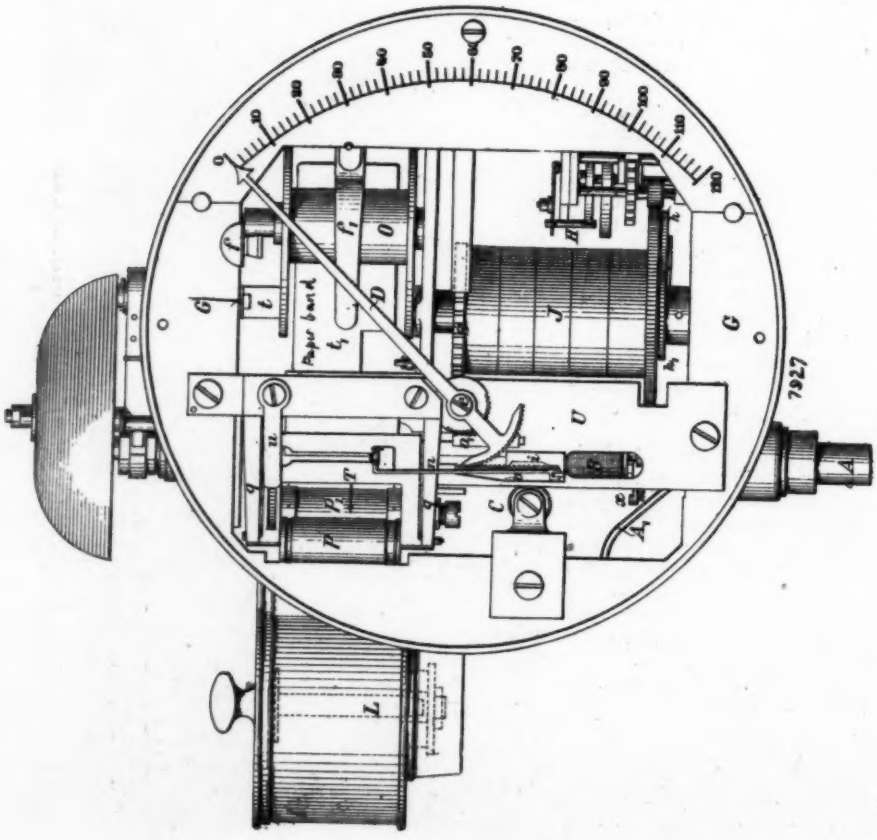


FIG. 7. "HAUSHAELTER" TACHOGRAPH.

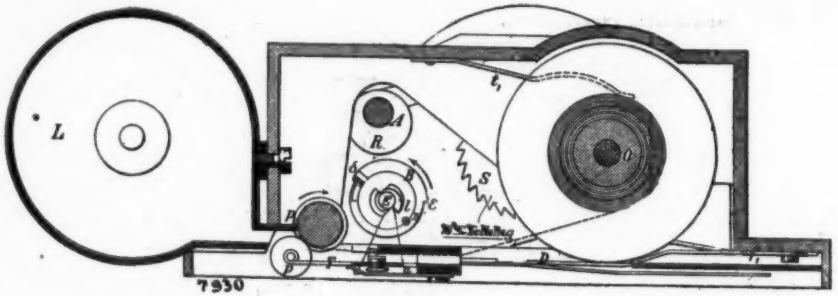


FIG. 9.

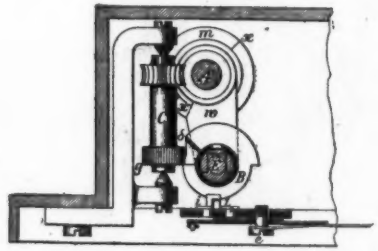


FIG. 10.

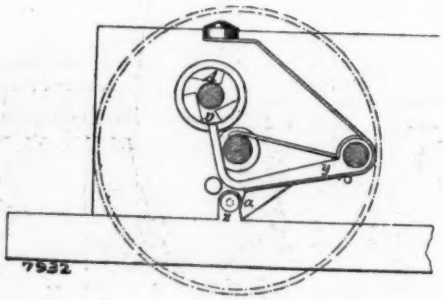


FIG. 11.

FIG. 12.

DETAILS OF "HAUSSHAELTER" TACHOGRAPH.

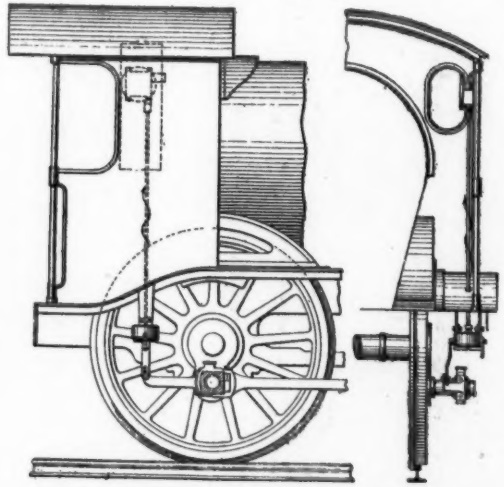


FIG. 13, SHOWING APPLICATION OF THE INDICATOR.

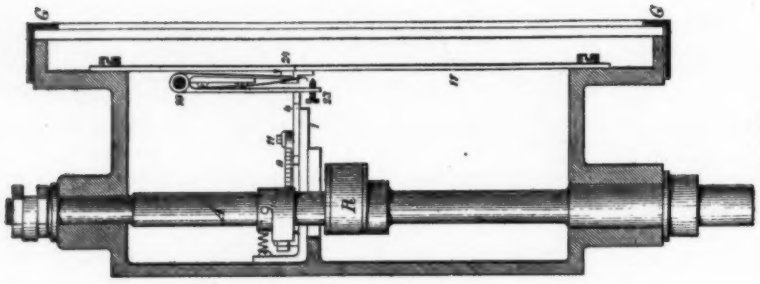


FIG. 15.

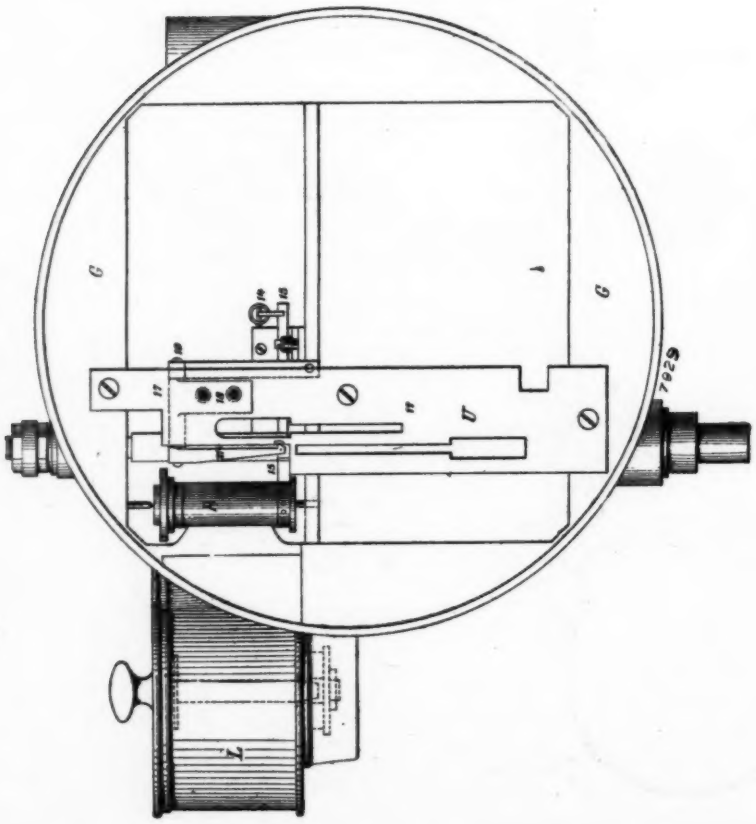


FIG. 14. "HAUSSHAELTER" TACHOGRAPH.

FIG. 18.

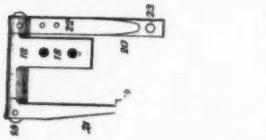
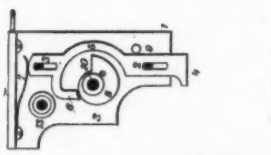


FIG. 17.



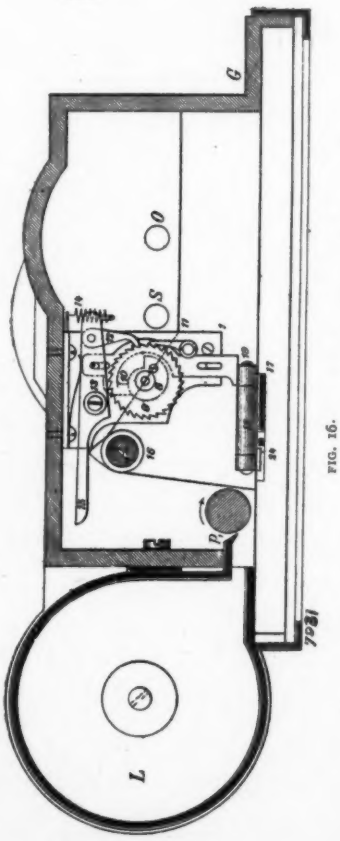


FIG. 16. "HAUSSHAELTER" TACHOGRAPH.

it at once gears with the barrel again at *b*. The barrel is hollow underneath, and, in falling, compresses the air, which softens the fall. The ingearing of the teeth *g* with the grooves of *B* is expedited by means of a collar, *m* (near the base of the main spindle, *A*) on which are milled three projecting lips, *x* having a height corresponding to the grooves in the barrel *B*. The shoulders, *x*, raise the plate, *w*, at the same time as the barrel *B*, which is also supported in the forked extension of this plate, *w* (see Figs. 8 and 10). The main driving spindle *A* takes its movement from the engine wheels and transmits it to the spur-gear spindle *C*, before mentioned, by means of worm-gear at *s* (Fig. 8). This explains the main parts of the gear for the measure of the *speed*. The *timing* of the speed measures is effected by the clockwork movement, acting on the second shaft *E*, before-mentioned. This movement is due to the pile of barrel springs *J* (Fig. 7) and the escapement *H*. The movement for the unrolling and rewinding of the paper band for the diagrams is derived from the train of five springs, which are sufficient, when fully wound up, to keep the clockwork going thirty minutes without any rewinding. The motion of the engine effects this rewinding automatically by means of an eccentric pitman feeder, *R*, on spindle *A* (Figs. 8 and 15). Every turn of the spindle *A* feeds the ratchet wheel *S* (see Fig. 9). The paper is now usually unrolled at a rate of four millims. per minute, as this gives a more distinct diagram by reason of the perforated points being well separated. These points are perforated once in every twelve seconds. The paper bands have a length of 45 metres, and a width of 5 centimetres. The roll-holder or spool carrier, *O*, is unwound by the driving-rollers *p.p* 1 (Figs. 7 and 9) which are actuated by transmission from the time-spindle *E*, and the band is re-rolled in the receiver *L*. As the paper is advanced, its two edges are perforated by holes spaced apart every six millims., which represent intervals of one and-a-half minutes. A second

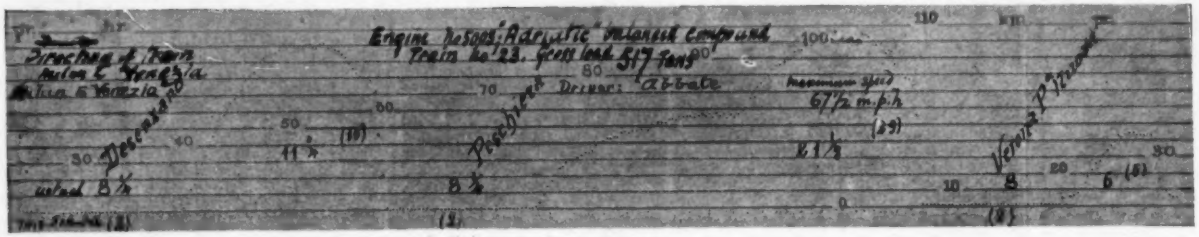


FIG. 19.—REPRODUCTION OF "HAUSSHAELTER" ORIGINAL DIAGRAM, SHOWING 7 FORBIDDEN SPEEDS.

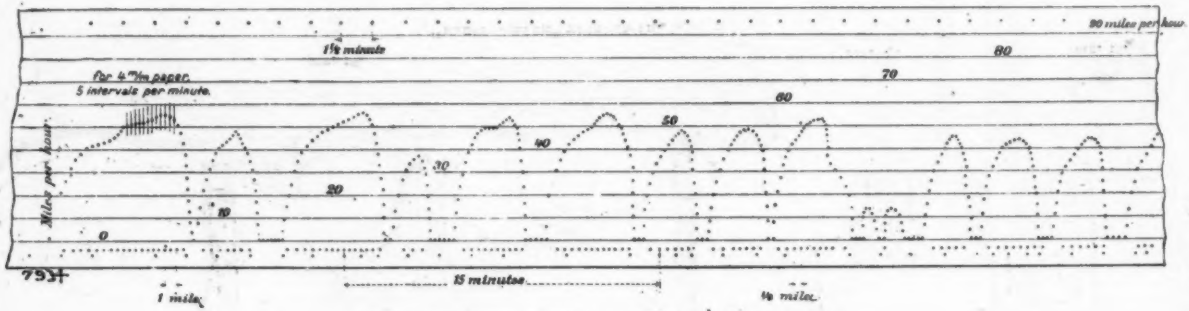


FIG. 20.—EXPLANATORY DIAGRAM. "HAUSSHAELTER" TACHOGRAPH.

row of holes in the lower edge marks the distances covered in kilometres and fractions thereof, the holes being separated by greater or less intervals according as the speed is, inversely, lesser or greater. This is effected by the eccentric 16 on the spindle *A* (Fig. 15) in connection with the mechanism marked in figures exclusively, in the drawings (Figs. 14 and 15).

The indicator-hand of this apparatus is moved once in twelve seconds by means of a toothed sector (Fig. 7), which gears with the rack, *v*, working in a slot of the plate *U*. Behind this rack there is a stud, *i* (Fig. 8) resting on the edge of the dropping barrel *B* so that, as this latter rises, the dial-hand turns. Accomplished one revolution in twelve seconds the barrel *B* falls, but the dial-hand remains held up by a spring. If the speed diminishes in the twelve seconds next succeeding, the barrel *B* does not rise to its preceding height, and the spiral feather, *d*, on the upper part of the barrel then bears down on the stud, *i*, of the hand *D*, forcing it to a position corresponding to the height attained by the drop barrel *B*. The speed-indication in every six seconds, or in half the time of the speed-recording, is effected as follows. The large-toothed sector of the hand *D* is geared to the recording mechanism through the long rack *v*, but the hand is provided with a second toothed sector, half the size of the first, geared with the short rack *v* ; and this second rack carries two studs, i_1, of shorter length than the stud *i*. As one-half of the annular surface of *k* (on the barrel *B*) and one-half of the spiral feather, project more than do their other halves, it follows that only these projecting portions strike on the studs i_1, and therefore the indicator-hand is moved twice in one revolution by the barrel *B*, and the speed is indicated twice as often as it is registered upon the paper band.

The bell on the top of the instrument is made to sound whenever the speed passes the limits allowed, and its recurrent warnings, which are very loud, become more frequent in repetition as the speed increases above the limits for which the striker is set.

(To be concluded.)

Sir William Arrol & Co., Ltd., to Widen Blackfriars Bridge.

INFORMATION is to hand that Sir William Arrol & Co., Ltd., of Glasgow, have obtained the contract to widen Blackfriars Bridge. The contract price is a little over £200,000.

The decision was come to at a recent meeting of the Bridge House Estates Committee of the London City Corporation. Tenders were submitted from fourteen large firms nominated by Sir Benjamin Baker, who has advised the committee throughout in the matter. Sir Benjamin was present at the meeting.

It is understood that the committee experienced considerable difficulty in making a selection, owing to the fact that some of the tenders were almost equal in price and merit.

Amongst the works which Sir William Arrol's firm have already carried out are the Forth and Tay Bridges, and the steel work of the Tower Bridge.

The widening of Blackfriars is expected to occupy three years. With the exception of the New Bailey it is the largest contract with which the City Corporation has had to deal since the Tower Bridge was built.

The widening has been rendered necessary by the decision to run tramcars over Blackfriars Bridge. The whole of the cost will be borne by the Bridge House Estates fund, no portion of the expenditure falling upon the rates.

Admission and Exhaust Valves used in Petrol, Gas, and Oil Engines.—III.

By EDWARD BUTLER, M.I.Mech.E., A.I.E.E.

(Continued from Page 339, Vol. 15.)

ON the expiry of the "Otto" patent in 1900, the 2-cycle engine with piston-controlled exhaust went into disuse on account of its rather greater cost of construction, but for large powers this engine has recently been again adopted with considerable success. Very large engines in considerable numbers are now being made with a single and double piston for use with furnace and producer gas; separate charging pumps being used for the supply of the air and gas to the admission ports. In order to further reduce the back pressure of the exhaust gases, it is sometimes the practice to use a water spray injection in the exhaust pipe immediately under the exhaust jacket round the ports communicating with the cylinder; this being done for the dual purpose of reducing the temperature around the ported belt surrounding the cylinder, and to diminish the volume of the gases.

By the use of piston-controlled ports for the admission and exhaust, the area for the flow of the gases to and from the cylinder can be increased from the customary proportions used in the 4-cycle class of engine, *i.e.*, from one-tenth to one-seventh, which latter proportion is shown in the table of cylinder and valve diameters given at the commencement of these articles—to an area approaching to one-fifth or even to one-fourth of the cylinder area. The port-ways being arranged around the full cylinder diameter, the area for a 20 in. diameter cylinder, for instance, will be some 70 in. with a width of 2¼ in. only; with the ports extending right round the cylinder and with spaces between of equal length to the openings, it will be seen that a total length of 30 in. can easily be obtained. It is questionable, however, if any material benefit can be derived from the use of port areas larger than one sixth the cylinder area, which give a velocity of inflow or outflow of the gases of less than 90 ft. per second, corresponding to a

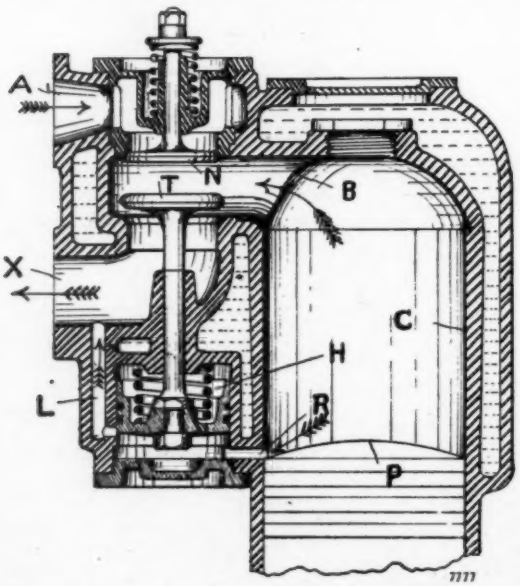


FIG. 15.—4-CYCLE MOTOR WITH AUTOMATIC ADMISSION AND EXHAUST VALVES.

piston speed of 850 ft. per minute, and results in a back pressure of very little more than 1 lb. per sq. in., provided short lengths of pipe connections are used with few obstructions and of a slightly amplified capacity.

The 4-cycle engine does not lend itself for working without valves as in the case of the 2-cycle engine, the nearest approach to the automatic working of the latter being obtained by a method of pressure actuated valve mechanism as shown in Fig. 15. Here it will be seen that a 4-cycle motor can be made without side-shaft or gear actuated mechanism of any sort, and, although not valveless, is entirely automatic in its working. The sectional drawing illustrates a vertical single-acting cylinder of the automobile pattern, the cylinder being provided with a port opening as in the 2-cycle type of engine, but on a smaller scale, and in this case serves to admit a small proportion of the gases under pressure at the termination of the power stroke, to flow under a piston *H*, fitted on the end of the exhaust valve stem *T*. The valve is shown thus lifted off its seat, the pressure under the piston being sufficient to open the valve, which is of a smaller diameter, against the spring fitted inside the piston used for closing the valve as soon as the motor piston *P* has arrived at the termination of its exhaust stroke, when it uncovers the port *R* to the crank chamber, and so liberates the penned-up gases under the valve piston *H*. In order to prevent excessive lift of the valve, its opening piston *H* uncovers a port leading to the by-pass outlet *L* as soon as the valve is sufficiently raised off its seat, and as soon as the pressure in the motor cylinder has been released the valve settles down so as to close the exit to *R*, and remains in this position until the motor piston *P* releases the pressure under the valve piston *H*, when it immediately closes. The exact timing of the exhaust opening can be determined by the lead of the port opening at *R*, the excess area of the piston *H* being sufficient to lift the valve and keep it open during the whole period of the exhaust stroke under all conditions of speed and load. An ordinary admission

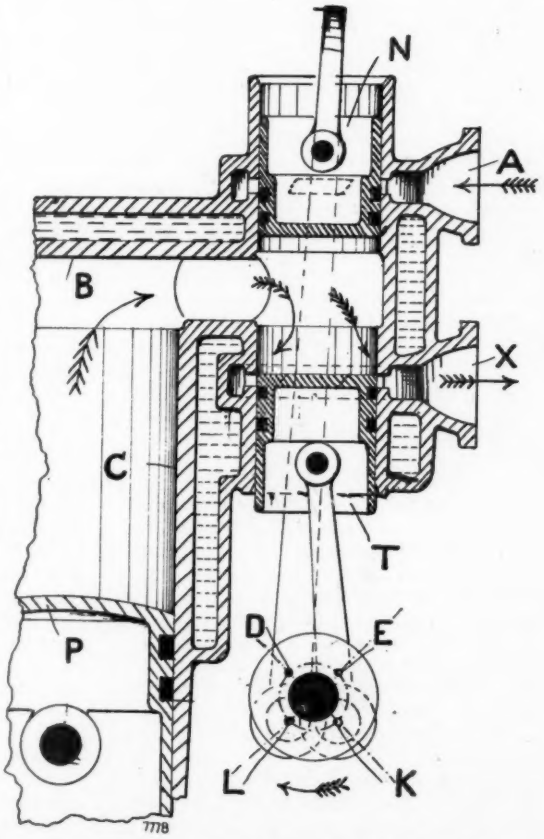


FIG 16.—4 CYCLE ENGINE WITH PISTON VALVES FOR ADMISSION AND EXHAUST.

valve (*N*), with spring and detachable seat is used, as in the case of a cam-opened exhaust motor, the mixture entering at *A* in the usual way and the motor exhausting at *X*. In order to remove the exhaust valve the inlet valve seat is taken off and the cover at bottom, when the piston *H* can be easily detached from the valve stem. In action, a motor of this construction can be made exceedingly fast and silent, and in combination with a thermo system of cooling water circulation the use of gearing can be entirely eliminated.

Another method of working a motor without cams or springs is shown in the illustration Fig. 16. In this case piston valves are used which open to the admission and exhaust in a similar manner to the working of the 2-cycle engines previously described. In this construction, the motor, which has a vertical single acting cylinder *C*, is provided with two smaller valve pistons, *N* and *T*, which are actuated by rods working from eccentrics on a half-speed side shaft. The motor piston is shown at the termination of its working stroke, and the piston valve *T* to be uncovering a belt of ports leading to the exhaust outlet *X*. At the end of the exhaust stroke the eccentric will have moved into the position *L* from *K*, and be about to close the exhaust, and during the admission, compression and explosion strokes, the exhaust valve piston eccentric will move round from *L* to *K*, and so be in the position for again releasing the exhaust. The admission valve piston *N* is now at *L*, and during the admission stroke will move from *D* to *E*. A motor constructed in this manner, although not so simple nor cheaply made as the ordinary cam-opened and spring-closed poppet valve motor, has some features in its favour, *i.e.*, an absolutely definite timing of the valve movements with quiet action at any speed.

In connection with this form of valve mechanism, a certain degree of additional expansion is obtained which was availed of by the Acme Company in the construction of a gas engine with valve pistons made of a larger diameter, so constituting, as it were, a compound engine. On examination of this design it will be noted that the valve piston *T* moves outward from *E* to *K* during the power stroke, and with a valve piston of twice the area of the motor piston an additional expansion to the charge can be obtained of about 50 per cent.

In the use of piston valves, which were commonly used in several 2-cycle gas engines, such as the "Palatine," "Niel" and "Charteris," &c., for controlling the transference of the charge from the charging pump at the side to the motor cylinder, and to time the communication between the combustion chamber and ignition tube, the valves were actuated direct from the crankshaft, and served their purpose well. A single valve of this kind cannot well be used to control both the admission and exhaust in the 4-cycle engine, as will be obvious upon an inspection of this problem, the time intervals between the periods of admission and exhaust being too close to allow sufficient movement of the valve. It is not also feasible in practise to traverse a piston valve fitted with rings across portways open to the pressure of the explosions, the effect being to close in the rings, cause leakage, and sooner or later bring about fracture of the rings.

The exhaust valve is generally considered the most important part in a 4-cycle engine of large size, it being necessary to always water-cool both the seat and the valve itself, and is also thought by many makers advisable to balance the force required to open the valve against the pressure in the cylinder at the end of the power stroke. The wear on the mechanism is very considerable unless some means, either for reducing the resistance opposed to the valve, or for giving it a preliminary small degree of lift so as to release the cylinder pressure, is adopted. In the case of a cylinder of 43 ins. diameter, having an exhaust valve of 14 ins. diameter, the pressure opposed to the valve's lift is over 3 tons. However, in many engines of large power no balancing action is provided,

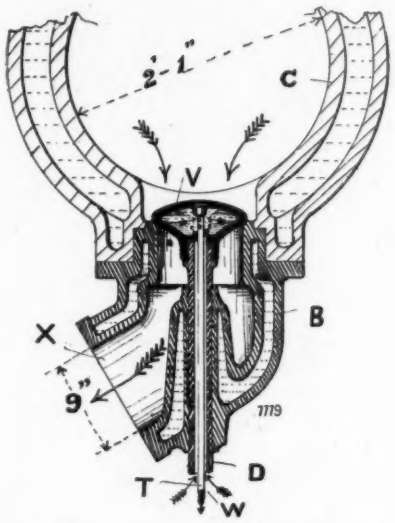


FIG. 17.—"DINGLER" WATER-COOLED EXHAUST VALVE.

and the actuating mechanism is relied on for entirely opening the valve against the full terminal pressure. In the "Dingler" gas engine, for instance, with a cylinder of 25 ins. diameter, a simple water-cooled exhaust engine, the water is further utilised to cool the valve. In the illustration (Fig. 18) the valve *V* is shown cast in one piece with a balancing piston, which makes a gas-tight fit in a cylinder bored in the cover *R*. The valve is hollow and controlled by a stem passing up through the water space to the cam lever *M*. The water from the cylinder jacket is forced into the nozzle over the valve, and thence flows down the inside of the valve and balancing piston and exits into the exhaust passage by the nozzle *Z*. The valve thus serves as a sort of water-pipe, and is kept nearly at the same temperature as the water itself. The drawback, if any, is that the water, in flowing round and over the valve piston head, prevents lubrication of the rings, and is liable to leak into the cylinder under certain conditions; but the chief objection is the liability to rusting of the valve piston, rings and cylinder.

In one form of "Crossley" balanced exhaus valve, shown by Fig. 19, and arranged in a casing forming part of the combustion chamber, the valve *V* is cast in one piece, with a balancing piston forming, as it were, an enlarged valve stem *N*. This stem piston is of an equal area to the valve *V*, and fits gas-tight in a cylinder bored out of the valve casting. Communicating with the under-side of this piston *N* is a portway *R*, which opens to the under-side of a small pilot valve *P*. Just before the time for opening the main valve *V*, the pilot valve is opened by the cam lever *M*, which action places in equilibrium both ends of the large valve, which is then easily raised off its seat by the cam lever *K* and steel stem *T*. In order to circulate water through the interior of the valve and balancing piston, the end

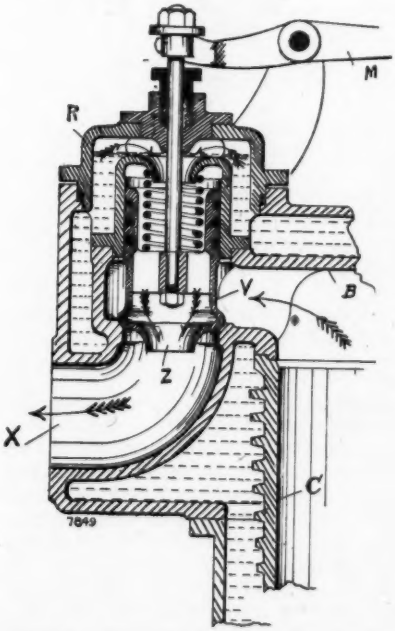


FIG. 18.—"DUNLOP" WATER-COOLED BALANCED EXHAUST VALVE.

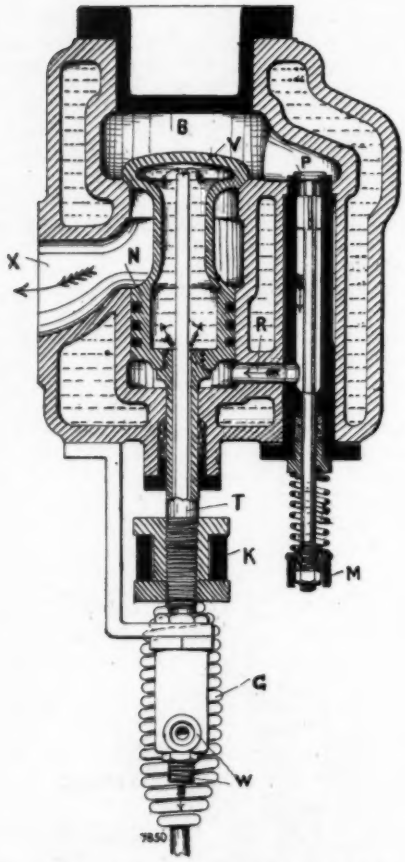


FIG. 19.—"CROSSLEY" WATER-COOLED EXHAUST VALVE WITH BALANCING PISTON AND PILOT VALVE.

of the stem *T* fits in a water case, which is connected to the inlet for water at *W* and outlet at the bottom, the water passing up the stem and returning by the inner tube in the usual way. The valve which is held down on to its seat by the tension spring *G*, is always kept full of water, and thus prevented from overheating.

In the illustration (Fig. 20) is shown a section of a type of balanced exhaust valve of ordinary construction, and adopted in certain engines of British manufacture, for example, the "Crossley," "National," and others. This is, perhaps, the simplest form of balanced exhaust valve, and has the merit of requiring no valve cover, the balancing piston *P* taking its place. The valve *T* is cast as before in one piece, with a piston head *P*, which is held down by a compression spring under simple adjustment from the crosshead placed over it. The valve is screwed on to a steel stem *D*, which fits water-tight in the water case *G*, supplied with water at *W*, whence it flows up the stem *D* and

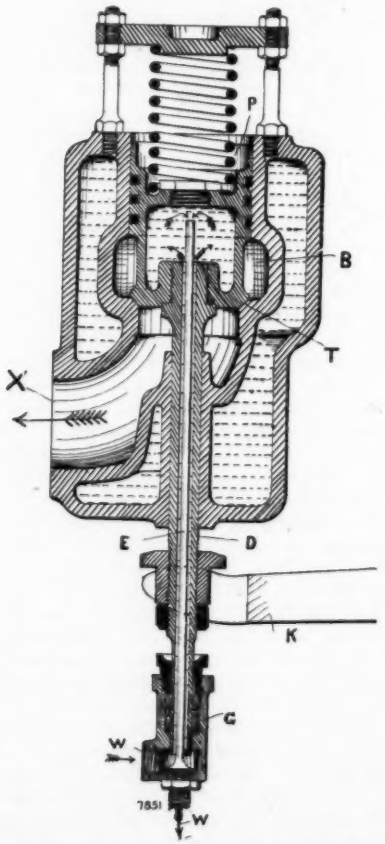


FIG 20.—COMMON TYPE OF BALANCED EXHAUST WATER-COOLED POPPET VALVE.

around the inner tube *E*, by which it returns to the outlet union nut at the under-side of the case *G*. All that is necessary in order to remove this form of valve is to slack back the cam collar on its stem and take off the spring head, when the valve is free to be taken out without breaking any joint. Another point in its favour is the free accessibility of the piston head for lubrication and detection of leakage.

The largest valve illustrated in these articles is the "Otto-Deutz" balanced exhaust valve, shown by the section at Fig. 21. This valve, as is usual in Continental practice, is arranged on the under-side of the horizontal cylinder *C*. The valve seat *L* forms a separate casting, and is separately water-cooled to the casing *A*, which is in turn bolted to the cylinder-jacket, and carries the exhaust pipe of 14 ins. diameter at *X*. The casting forming the valve seat and guide is held up to the cylinder—a gas-tight fit—by spring washers and bolts to allow for any difference of expansion. The valve itself is cast hollow, and is provided with a balancing seat at *S*, by which the valve *V* is placed in a state of equilibrium by the passages *B*. The valve is thus seen to have a double seat, only one of which serves for the exhaust of the gases, the under seat being simply used to give a balancing effect. The valve being placed under the cylinder, accumulation of dust from the gases is prevented, and by the construction, which is self-explanatory, the exit of the exhaust gases is permitted an exceedingly free escape, and is surrounded on all sides by water-cooled walls. The valve stem is screwed into the valve casting in the usual way, and fits in a water case at bottom provided with a gland leakage tray *Y*, for running off escape of water. The cooling water to the valve is carried up the stem and returns by an inner tube, where it enters at the highest point under the valve crown, the space around, and in the tube, being in connection with the water service pipes *W*. In order to prevent leakage of exhaust gases caused by any slack around the valve stem and the central guide bearing, this is provided with packing rings and with a supplementary asbestos packing box held up by the valve spring. The cam lever *K* lifts the valve by a crosshead provided with a pin at each side, unto which is fitted friction rollers for engagement with the lever fork end. The crosshead fits on the valve stem against a shoulder and permits the ready removal of the valve up through the combustion chamber and out by the opening at the top provided for the inlet valve. In this manner only one pressure joint is broken to remove both the admission and exhaust valves, and readjustment of the connections between the exhaust valve and operating mechanism is avoided.

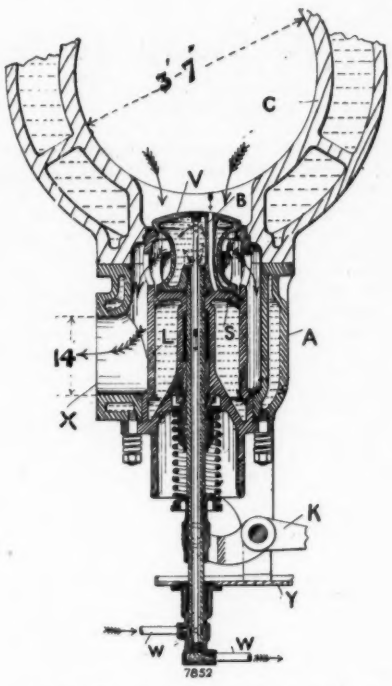


FIG. 21.—"OTTO-DEUTZ" WATER-COOLED AND BALANCED EXHAUST VALVE.

(To be continued.)

A Study in Bevel Gear Cutting.

"Dubosc" Automatic Bevel Gear Cutter, working without Template.

By the courtesy of Messrs. Selig Sonnenthal & Co., Ltd., of 85, Queen Victoria Street, E.C., the licensees, we are enabled to illustrate and describe a new bevel gear cutting machine of the planer type capable of cutting bevel gears geometrically correct entirely automatically. General views of the machine are given in the half tones, detailed drawings being reproduced in Figs. 1 to 11.

The machine will be seen to consist of two main portions, namely, the dividing mechanism, whereby the central spindle or mandrel on to which the blank is clamped, is operated; and the mechanism for operating the cutter and determining the form of the tooth. The only motion of the blank is that of simple rotation and is imparted through the mandrel and large dividing wheel by worm and change wheels driven from the single belt pulley. This simple arrangement allows the mandrel to be firmly supported at both ends and consequently permits heavy cuts to be taken on the blank with safety.

The cutting and profiling of the teeth is made by a tool of the planer type which moves backwards and forwards in lines converging towards the apex of the cone to be worked, and which rests on a directrix traced virtually on a sphere having its centre on the top. The directrix chosen by the inventor is the involute of the circle. The profiling motion of the cutter is imparted by the mechanism seen to be pivoted vertically between the arm and table of the machine, and which is driven by the stepped pulleys conspicuous in the opposite illustrations.

The special advantages of the machine, which has been primarily designed for motor car work, are its all-round utility and its power; no special arrangement or accessory for each wheel to be cut is necessary, and, further, much of the usual preparatory work in the way of designing, calculations or adjustments are dispensed with. It will cut gears equally well of any material, namely, mild steel, hard steel, cast iron, brass, leather, red fibre, ebonite, &c., and of sizes ranging from the smallest of diameters up to about 30 ins., and from $\frac{9}{16}$ in. pitch for smaller gears, up to $1\frac{9}{16}$ ins. pitch for the larger gear. It is also suitable for mitre gears up to about 20 ins.

Another important feature of the machine is that it only takes about five minutes to fill up the instruction sheet from the index pages supplied with the machine, for cutting any pair of bevel gears, for the operator to work from; the latter being then able, by the help of the instruction sheet, to put the machine in readiness for starting within fifteen minutes. The machine is entirely automatic both in feeds and reversing motion, one man being able to attend to two machines, or even four, when it is a question of cutting gears in large quantities.

To give an example of the output of this machine, we may state that thirty-four teeth were cut in the solid on a hard steel gear wheel of 15 ins. diameter in four hours.

Having thus briefly outlined the chief characteristics of the machine, we may proceed to examine it in detail, the principle on which the machine works and the mechanical details being of the greatest interest.

Principle of the Machine.

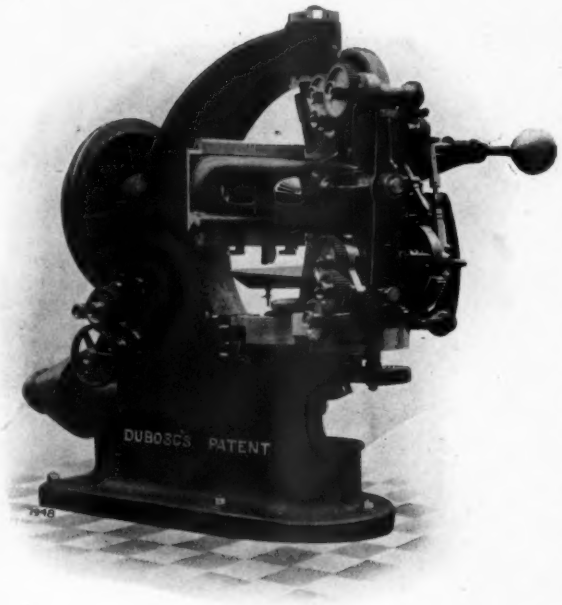
The machine being of the planer type, it is evident that the diameter of the blank is not an essential detail for determining and adjusting the elements called upon to produce the work, as the tool is able, within the limits of the size of the machine, to cut an indefinite cone, of which the work to be done is but a part.

In order to determine this toothed cone two data are sufficient—the angle at the apex of the primitive cone and the division or number of teeth. Of all the modules progressing from zero to infinity which can be measured on this indefinite cone, it suffices to know one, and that may be chosen which refers to a sphere of 1,000 millimetres radius, that is:

$$m_1 = \frac{2{,}000}{z} \sin. A.$$

This fundamental module M_1 may be measured from the module M, measured on the primitive diameter of the back of the teeth of the blank, if the distance of the extremities of the above diameter at the top of the cone is known, as:

$$m_1 = \frac{1000}{d} m.$$



FRONT VIEW OF DUBOSC'S BEVEL GEAR CUTTER.

Let us now suppose that the tool be fixed to a system composed of two frames, the second frame being able to oscillate round a solid axis of the first, and this latter being able to oscillate round a fixed axis.

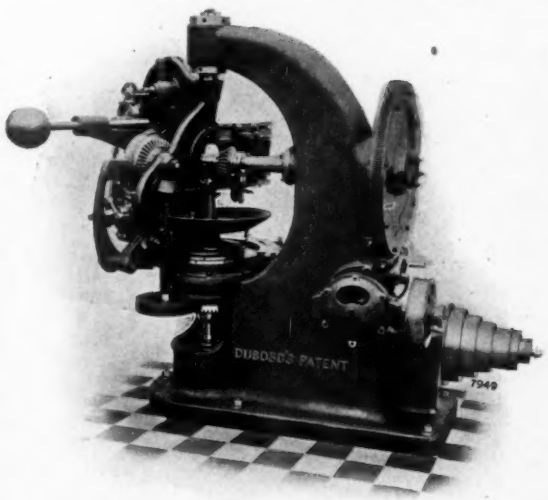
The two axes of rotation are perpendicular to each other, and their point of intersection is at the apex *V* of the blank centre of the sphere of 1,000 millimetres radius on which it is supposed the directrices virtually traced.

If the point of the tool be fixed at the distance of 1,000 millimetres from the apex *V*, the angular movements of the first frame will move the point of the tool along an equatorial circle, and the movement of the second frame will move it along the meridians.

Let us suppose, along the equator, a series of equal elementary movements; if at these abscissæ, variations of the ordinate equal among themselves, should correspond on the meridians, the line described by the point will be a large circle, and if the backward and forward motion takes place, the surface created will be a plane.

If on the other hand, the variations of the ordinate are variable for constant variations of the abscissa, the point will trace a curve upon the sphere, which will not be a large circle, and the backward and forward movement will create a conical surface, whose curve will be the directrix.

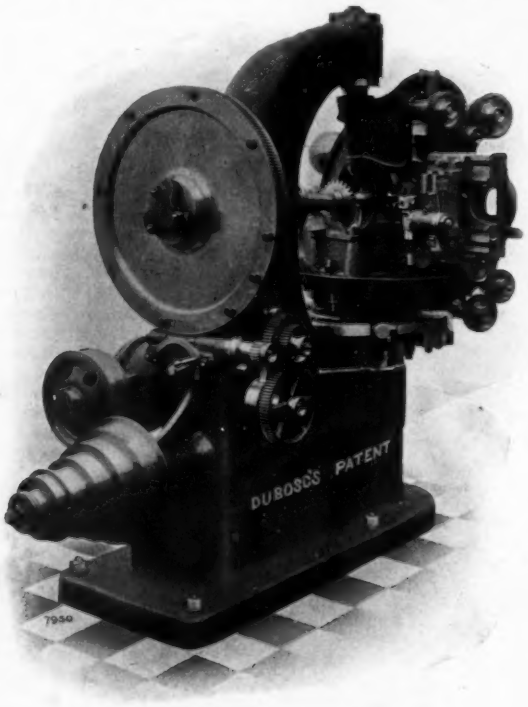
In the first case we know that the outline of the involute, the odontoid of the rack, is a straight line (on the plane), or an arc of a large circle (on the sphere) having, in ratio to the axis of the tooth, an incline equal to the obliquity of the pitch line (the obliquity is measured by ratio to the normal, at the



SIDE VIEW OF THE MACHINE.

line of centres). It is also known that a limit is generally allowed for the number of teeth on a wheel for which the profile of the tooth may be taken to be practically equal to the tooth of a rack; this limit is fixed at 135 teeth; to be exact, at 150.

The equatorial plane of the sphere being the mean plane of a tooth, and the constant ratio between the ordinates and the abscissæ y/x being equal to tang θ, the



BACK VIEW OF THE MACHINE.

surface created by the point of the tool will be an inclined plane of the angle θ on the mean plane of the tooth, that is to say, we shall have created one of the sides of the tooth of each bevel gear having 150 teeth or more. It is therefore easy to find out the elements which will have to produce the movements of the secondary frame, so that their relation to the simultaneous movements of the primary frame be equal to tang θ.

In the second case, that is to say that in which the ratio y/x is variable, if the directrix is an involute arc, and precisely the arc of the spherical involute, which suits, as odontoid, the gear wheel being cut, and placed so that the mean plane of the tooth to be profiled coincides with the equatorial plane of the sphere, the point of the tool will create one of the two sides of this tooth.

Therefore the movements of this secondary frame must be worked by a device connected to that which determines the movements of the primary frame, so that the point of the tool describes, on the sphere of a radius of 1,000 millimetres the involute of the odontoid suitable for the wheel being cut.

The device, which outlines the form of the tooth, is one of the principal features of the machine.

The extreme position of this device supplies the extreme outline which was examined in the first case. Thus, this instrument enables us to trace on the sphere of 1,000 millimetres radius, the series of odontoids suitable for all wheels, from the smallest pinion up to a 150 toothed wheel, on a determined high module, which we may call m, and which is fixed by the proportions of the instrument itself.

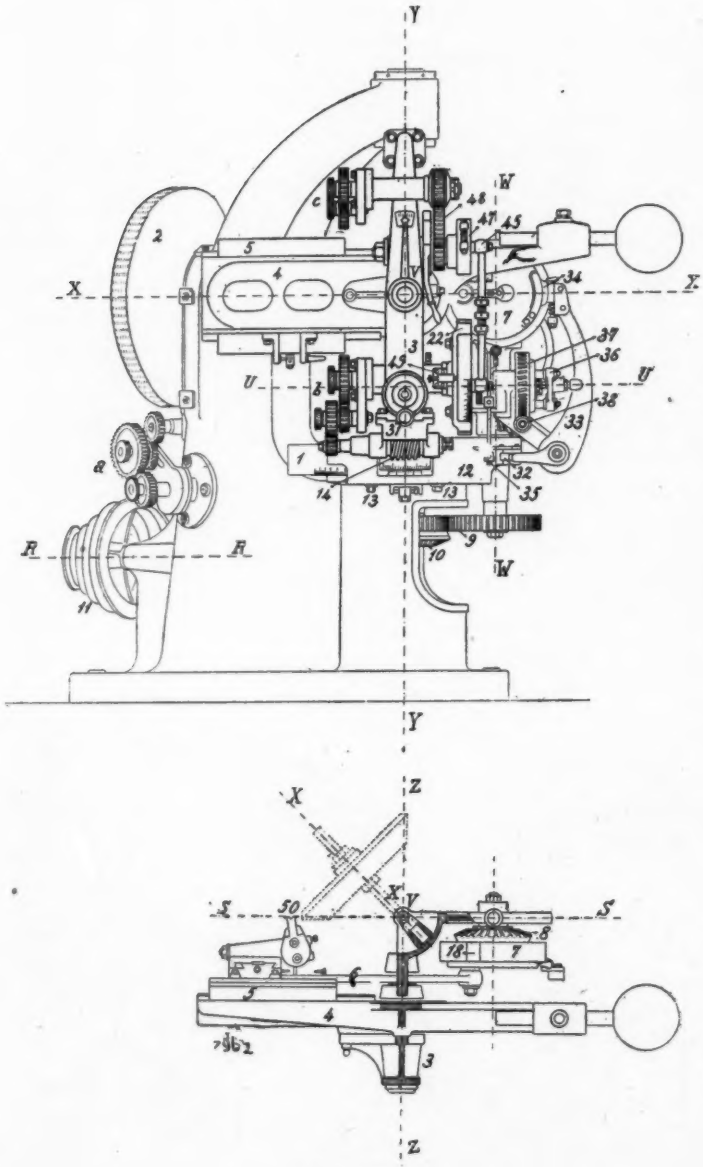
However, for cutting a wheel whose module at the back of the tooth is m, we must have, for directrix on the sphere of 1,000 millimetre radius, the odontoid agreeing with the data Z and a of this wheel) relating to the module m_1

$$m_1 = \frac{1000}{d} \quad m = \frac{2000}{z} \sin. A.$$

It is necessary therefore to insert between the profiling apparatus and the tool, two reducers or multiplicators, causing a reduction or increase in the same proportion $\frac{m}{m_1}$ in the abscissæ and the ordinates of the curve.

These reducing or multiplicating gears form part of the mechanism called the pitch device.

And now to complete this sketch of the whole, it suffices to add the divider, by which the work, after one side of the tooth is cut,


Y
W
48
47
45
c
2
5
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X
X
34
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37
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U
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38
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14
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10
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R
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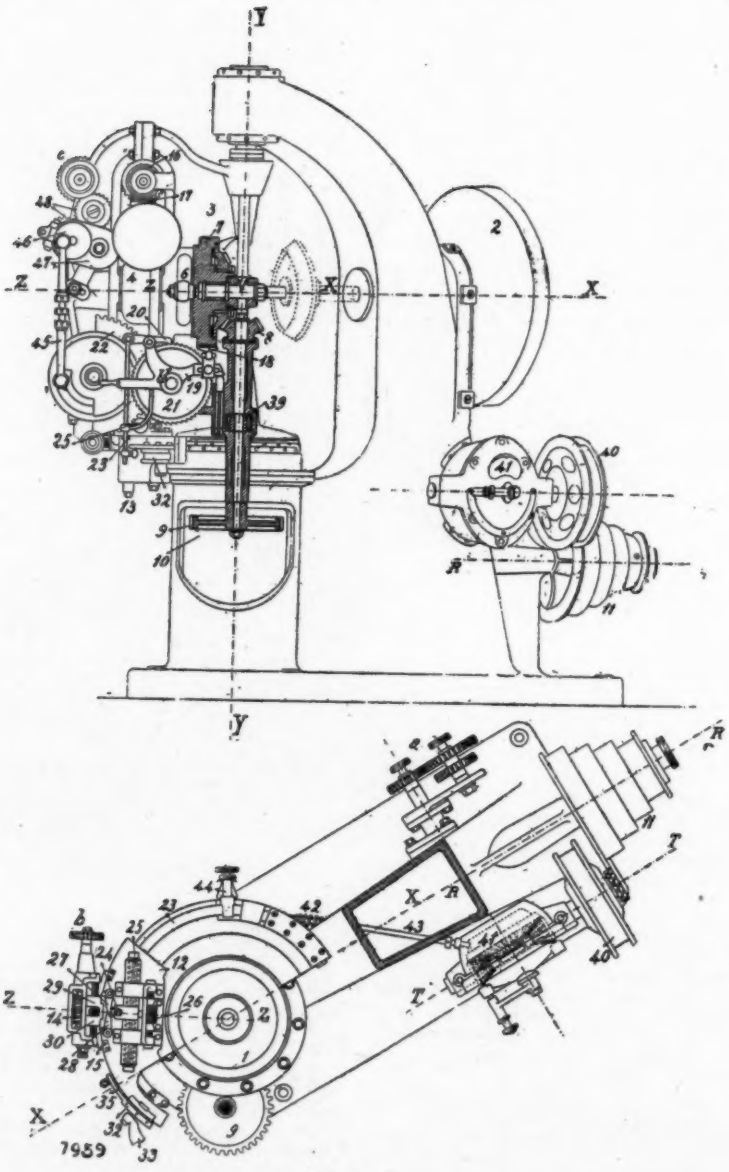
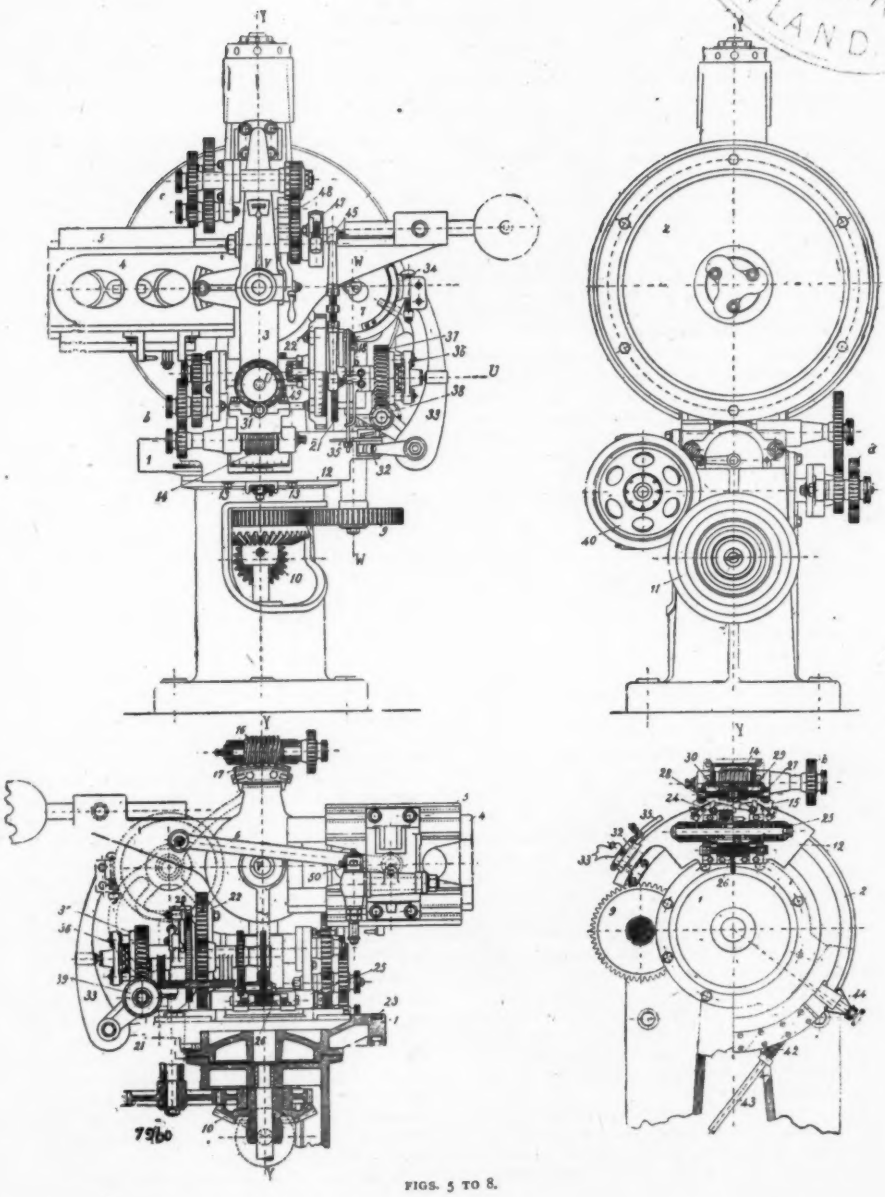
FIGS. 1 AND 2.



FIGS. 3 AND 4.

INSTITUTION OF ENGINEERS IN SCOTLAND



FIGS. 5 TO 8.

turns round on its axis a fraction of a revolution, to allow the tool to cut the next tooth on the same side. When all the teeth are cut on the one side, the same operations are repeated for the opposite side, after reversing the profiling apparatus, that is to say, after arranging to supply, for the same abscissæ, the same ordinates as for the previous operation, but with negative values.

In short, each tooth being determined by three elements: the number of teeth (divisions), their size (the module) and their shape, the machine is composed essentially of three parts: the divider, the pitch device and the profiling apparatus.

Working of the Machine.

The tool, is as above stated, provided with a backward and forward movement directed constantly towards the apex of the cone being cut, and creates a taper surface having for directrix an involute arc virtually traced on a sphere having its centre at the apex of the cone, this involute arc being in each case suitable for the teeth of the wheel to be cut.

It is well to point out that this tool is not a former tool, but a simple planer tool, working at its point, which is slightly rounded, thus ensuring the possibility of taking heavy cuts, such as obtained on a shaping machine.

The round point of the tool has a radius suitable for making the required connection between the base of the tooth and the bottom of the notch.

When the tool reaches the bottom of the notch, its oscillating motion ceases and it returns quickly to its starting point, the point of the tool passing in the opposite direction over the involute arc outside the work. The work, at this stage, revolves automatically round its axis, to the angle appropriate to its division, whilst the tool resumes its oscillating and penetrating motions, for making the second notch and outlining the second tooth, this series of operations are repeated automatically for a complete revolution of the work, the tool outlines successively all the teeth on one side; to outline the teeth symmetrically on the other side, it is only necessary to re-adjust the position of the tool, and to reverse the profiling apparatus which gives the curvilinear feed.

For large teeth, a notching operation precedes the two symmetrical outlining or profiling operations. The notching tool is stepped so as to be able to remove as much stock as possible.

Needless to add, whilst notching, the tool is fed on a plane, the profiling device being thrown out of gear.

The tools, both for notching and profiling, are generally provided with a double cutting edge, and remove stock in both the forward and backward stroke, the feed acting each way.

The machine, however, is arranged for allowing a tool with a single cutting edge to be used, the feed then only acting one way, should the shape of the work require it.

General Description.

The frame or body of the machine includes a circular table (Figs. 1 to 10) and the support of a horizontal spindle *XX*, bisecting the vertical axis *YY* of this table at *V*.

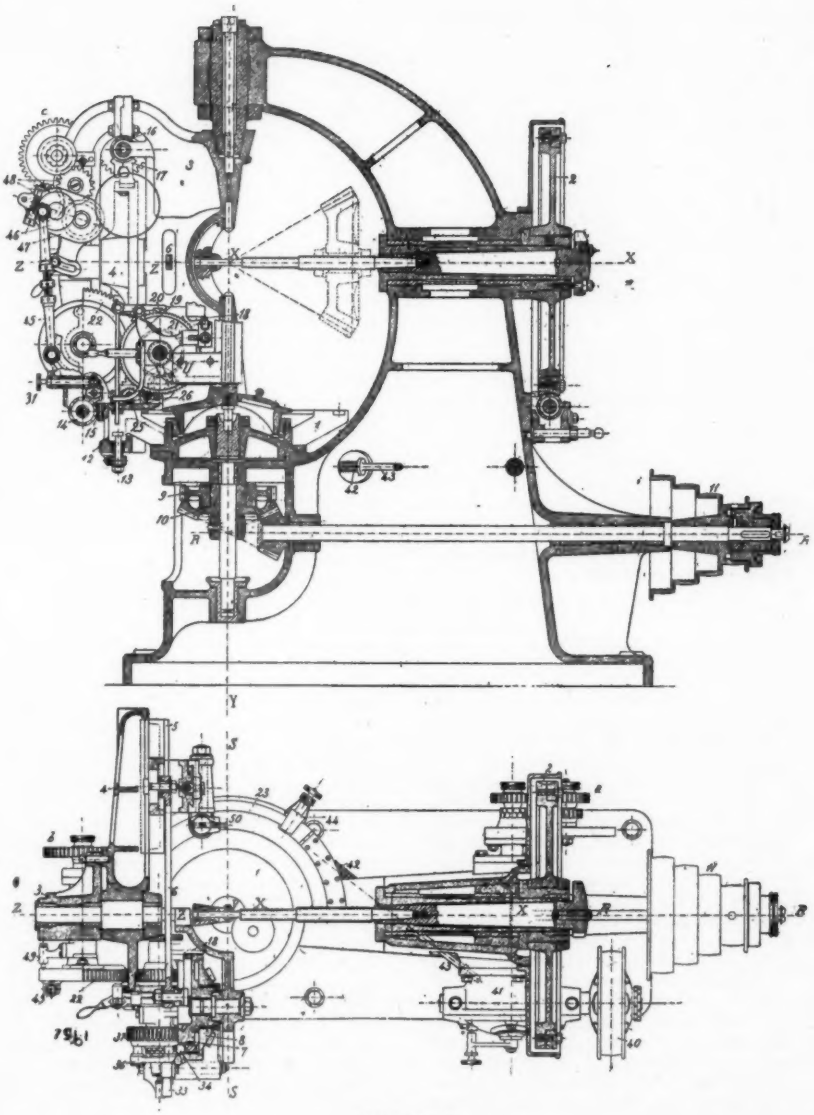
The blank is fixed on the spindle *XX*, so that the apex of its cone is the point *V*. A frame 3 (Figs. 1, 2, 3, 5, 9, 10), adjustable round the vertical axis *YY*, supports the horizontal axis *ZZ* (Figs. 3, 4, 9, 10), passing over the point *V*, and is the oscillating axis of a second frame 4, serving as a slide to the tool rest 5 (Figs. 1, 3, 5, 7, 10).

This slide receives a backward and forward motion by means of a connecting-rod 6 (Figs. 3, 7, 9, 10, crank-disc 7, and gears 8.8 (Figs. 2, 3, 5, 10), 9.9 and 10.10 (Figs. 1, 2, 5, 7, 8, 9) from the main spindle *RR*, that is to say, from the driving pulley 11. (Figs. 1, 2, 4, 6, 9, 10.)

The auxiliary wheel 9, whose vertical axis *WW*, carried by the adjustable frame 3, and which also carries the crank-disc 7, is free to move round the driving wheel (which has its axis at *YY*), and makes it possible to transmit the rotary movement of the splndle *RR* to the crank-disc 7, no matter what be the position of the frame 3.

A slide 12, capable of moving in a circular direction on the table 1, and of being fixed in any position required on same (the table being graduated for this purpose), draws the frame 3, to which it is keyed by a removable pin; the graduation should indicate the semi-angle at the apex of the primitive cone of the gear to be cut, the slide being fixed in this position by one or two bolts, 13 (Figs. 1, 2, 5, 9), the head of which is held in a circular slot in the table, the tool point should be in the vertical plane *SS* (Figs. 3, 10), tangent to the above-mentioned cone; its height is then adjusted so that this point touches the pitch line, and can pass over it in its backward and forward motion.

If the pin which connects the slide 12 to the frame 3 is now removed, and supposing the slide, now become fixed, be provided



FIGS. 9 AND 10.

with two adjustable stops for the purpose of limiting the oscillations of the frame 3 round the axis *YY*, the latter, driven by a worm 14 (Figs. 1, 4, 5, 8, 9) by alternating rotations, and engaging in a toothed sector 15, forming part of the slide 12 made stationary, will be able to move, whilst oscillating between the two stops, round its mean position, so that the point of the tool traverses the angular space comprised between the cones which limit the height of the tooth to be cut, and produces a notch, the mean plane of which will be the horizontal plane passing through the axis *XX* of the work, if, during the angular motion of the frame 3 round *YY*, the position of the frame 4 in ratio to 3 will have remained invariable.

Should, however, the frame 4 revolve round *ZZ* at the same time as 3 moves, the point of the tool will generate a plane (no longer a meridian plane of the cone), if the two elementary simultaneous motions have a constant ratio; or even a taper surface with a curved directrix, if the two elementary simultaneous motions have a variable ratio. The law of variations of this ratio determines the nature of the directrix of the taper surface generated.

Pitch Device, for Determining the Size of the Teeth.

The crank-disc 7 (Figs. 1, 2, 3, 10), which works the connecting rod, is fitted at its periphery with a cam 18 (Figs. 2, 3, 5, 10) (or with two similar cams diametrically opposed if the tool has a double cutting edge), which at each turn (or half turn) of the disc causes the lever 19 to oscillate, this lever being fitted with a balance weight or spring, which works, by means of a pawl, the ratchet 21, fitted on a spindle *UU*, which, by an immovable gear 22 and the set of interchangeable gears *b*, transmits the movement to the worm 14, which has been already mentioned for the tool feed.

The stop takes place at the end of the stroke in the following manner:—

A prismatic box 25, sliding in a guide of the slide 12, contains two spiral springs separated by a small piston, which is worked by the spindle *UU* through a slot hole in the box, by means of a screw and nut arrangement and a set of pinions, the latter of which are seen at 26 (Figs. 4, 7, 8), by the piston working either to the right or left, the box 25 being held by a hook (27 or 28) pivoting on 12, one of the two springs is pressed against one of the ends of the box.

Two drivers, 29 and 30, fixed to the frame 3, the distance between them being adjustable, strike at each semi-oscillation of the frame against a catch of 27 or 28, releasing the box 25, which under the pressure of the taut spring is instantly moved, and by a pin 24, which passes freely through the slide 12, sets in motion, in an angular direction, a link 23 (Figs. 4, 7, 8, 10) lodged in a circular slot of the table 1.

Of the two alternating motions of the link 23, that which is effected at the end of the working period causes, by the mechanism 32 (Figs. 1, 4, 5, 8, 9), the lever 33 to oscillate, which, by raising the pawl 34, makes the crank disc 7 loose on its spindle, and stops the backward and forward motion of the tool. At the same time the strip 35 (Figs. 1, 4, 5, 8) forming part of the mechanism 32 raises the pawl 20 (Figs. 2, 7, 9), releasing the ratchet 21 which gave the feed to the tool. The same motion causes the lever 33 to throw into gear the wheel 37, on the spindle *U U*, with the worm 38, which during the feed was loose, and which, driven by the vertical spindle *W W* by means of a pair of helical wheels, one of which is seen at 39 (Figs. 2, 7), gives the spindle *U U* a quick rotary motion in the opposite direction, to bring back the frame 3 to its starting position for the same set 22, *b*, 14, 15, which had been worked by the action of the ratchet 21 at the working period.

During the return of the frame 3, the second spring enclosed in the box 25 will be compressed in its turn, and the second driver 30 unhooking 28 (when the tool has returned to its starting point), the box 25, set free, will pull, by the peg 24, the link 23, and turn it to the same angle as at the previous corresponding action, but in the opposite direction. This movement of the link 23, acting on 33 and 35, will throw into gear on its spindle the crank-disc 7, gearing up also the worm wheel 37, and making the pawl 20 drop on to the ratchet 21; then the backward and forward movement of the tool starts again, as well as the pawl feed motion, whilst the return device 37, 38, 39 remains idle, and the first spring of the box 25 starts tightening again for preparing the next release and return.

The Divider.

The moment the tool resumes its period of work, the latter turns on its axis to an angle corresponding to its division, so that the next tooth can be cut. This is how this movement takes place:

A pulley 40 (Figs. 4, 6, 10), driven from the countershaft, is fixed by friction on the spindle *T T*, which, by means of the bevel gears 41, and the set of gears *a*, is able to

work the worm of the large wheel 2 (Figs. 1, 2, 6, 9, 10) keyed in the socket of the mandril *X X*, carrying the work. A hole is drilled on the periphery of the bevel wheel 41, into which is driven, by the pressure of a spring 42 (Figs. 4, 8, 9, 10), the end of a rod 43. As long as the rod is held in this hole, the wheel 41 and the gearing which it drives are forced to remain at rest, the pulley 40 running loose between its friction plates. The link 23, however, when released for effecting the period of work, works also a pawl motion 44 which, driving back the rod 43, releases the wheel 41; the latter, by the action of the belt, makes a complete revolution, after which the spring 42 again forces the rod into the hole, and the whole stops again.

Now, the interchangeable wheels *a* can be arranged for each wheel to be cut, so that, for any complete revolution of the wheel 41, the angular movement of the large wheel 2 will correspond exactly to the division of the wheel to be cut.

The Profiling Apparatus.

The mechanism which has to transmit the action of the wheel 22 (Figs. 1, 2, 5, 7, 9, 10) to the worm 16, for effecting angular adjustments of the secondary frame 4 around he axis *Z Z*, is composed as follows, viz.:

The toothed wheel 22 receives, in a circular slot, the journal of a head of a connecting rod 45, the journal at the other end being fixed excentrically to a small disc 46, the latter itself pivoting excentrically on the part 47, working as a crank. (See also Fig. 11.)

On the spindle of this part is keyed the first of four pinions 48, constituting the well-known mechanism for the reversing motion. The spindle of the last of these four pinions carries at the other end an arrangement for receiving the interchangeable wheels *c*, which transmit the motion to the worm 16, for the angular adjustments of the frame 4 around the axis *Z Z*.

The purpose of the wheels "*c*," which are, for each gear to be cut, identical and arranged identically to those "*b*" of the pitch device, is to realise for the ordinates of the directrix curve generated by the tool, the same reduction which affects the abscissæ of this curve by means of the wheels "*b*."

The toothed plate 22 being in the ratio of 8 to 3 with its driving pinion, and this pinion making invariably a complete revolution, for each tooth of whatever wheel is being cut, it follows that the plate 22, and therefore the bottom journal of the connecting rod 45, make invariably for each tooth

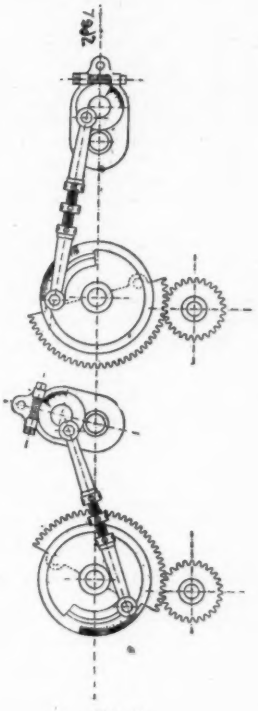


FIG. 11.

cut, three-eighths of a revolution. Each of the two journals of the connecting rod 45 has an index finger capable of moving along a circular graduation engraved on the plate 22 and on the disc 46.

Before starting the work, the two index fingers are arranged opposite the division representing the number of teeth of the wheel to be cut, the parts 22 and 47 being brought back to the starting point (this being invariable for any wheel to be cut), and are kept in this position by means of two pegs, one of which is seen at 49 (Figs. 1, 5, 10); to enable the two index fingers to be set, the connecting rod 45 may be lengthened or shortened by means of a right and left hand screw.

Having removed the two pegs, the machine is started, and the plate 22 starts rotating in equal elementary movements determined by the uniform action of the pawl 20 on the ratchet 21, whilst the mechanism we have just described will give to the crank 47, and therefore to the frame 4 also, variable

angular motions (and even leading in the opposite direction, towards the end of the feed, for cutting pinions having a small number of teeth). The law of variation of these movements is determined, in each case, by the position which has been given to the index finger on their graduations.

Now these two graduations, in ratio to the proportions of the mechanism (excentricity of the two journals of the connecting rod in relation to the centres of the parts 22 and 46, and excentricity of 46 in relation to the axis of the crank 47), are established so that for each wheel to be cut (defined by its number of teeth Z), the directrix of the taper surface generated by the tool will be the involute arc which corresponds to this wheel, the two index fingers being opposite the number Z.

The extreme case, where the directrix should be a straight line, is indicated by the division $Z=150$; that is the only case in which the secondary frame 4 makes constant elementary movements, like those of the principal frame 3, the axis of the connecting rod then moving parallel to the line which connects the centres of parts 22 and 47.

Dimensions of the Machine, Details and Accessories.

At present only one size of the machine is made. This size takes any wheel which can be inscribed in a sphere of 29½ ins. diameter at the back of the tooth if the angle at the apex of the primitive cone be very obtuse, and 19⅝ ins., if this be a right angle.

It is possible to make assortments of bevel wheels, that is to say, wheels inscribed in the same sphere and having the same module or pitch, these wheels being interchangeable if the variation of angle of their axes is permitted. The semi-angle at the apex of the primitive cone of the wheel being cut may vary from 8° up to 90°, that is to say, it is possible even to cut *flat* wheels (angle at the apex of the primitive cone =180°).

As regards the module, there is no limit; all current pitches are permitted.

From the preceding description it is easy to see that this new machine, by its ample pitch, diameter and angular capacities, has a general all round utility.

The advantages of dispensing with a copy are now much appreciated by the great majority of mechanics, the machine working without any copy doing away with a very delicate preparatory work, in which mistakes are very apt to be made and which has to be done all over again every time a fresh gear has to be made. The only thing to be said in favour of the machine working from a copy is that it is possible to cut the teeth to any profile—epicycloidal, involute or otherwise, according to the choice of the maker of the machine. It remains to be agreed upon as to the most suitable obliquity to assign to the pitch line for these involute teeth, and it is to be hoped that this point will be soon settled.

Whilst awaiting this complete unification, the machine we have just described can be made to order for any obliquity of pitch line required, although the machine now being made is arranged to give an obliquity of 22½ degrees.

Aërial Ropeway for the Preston Corporation.

An interesting installation of an aërial ropeway has recently been carried out for the Preston Corporation, for the purpose of removing clay from Spade Mill Reservoir to the Alston Reservoir at Longridge, a distance of 1¾ miles. Incidentally it may be mentioned that the clay was used for raising the banks of the latter reservoir about 11 ft., and its removal from Spade Hill was for the purpose of enlarging the reservoir at that place.

The ropeway was designed and constructed by Messrs. Bullivant & Co., Ltd., of 72, Mark Lane, London, to the requirements of J. H. Smethurst, Esq., the resident engineer.

The ropeway passes over a number of farms, and one of the conditions was that there should be no disfigurement of the scenery, and as little damage as possible done in erecting. A reference to the illustrations will show that these conditions have been fully complied with.

The quantity to be carried was 100 tons per day of ten hours, and it was at the special request of Mr. Smethurst that the individual loads were fixed at 5 cwt. with the idea of ultimately increasing the capacity of the line by the

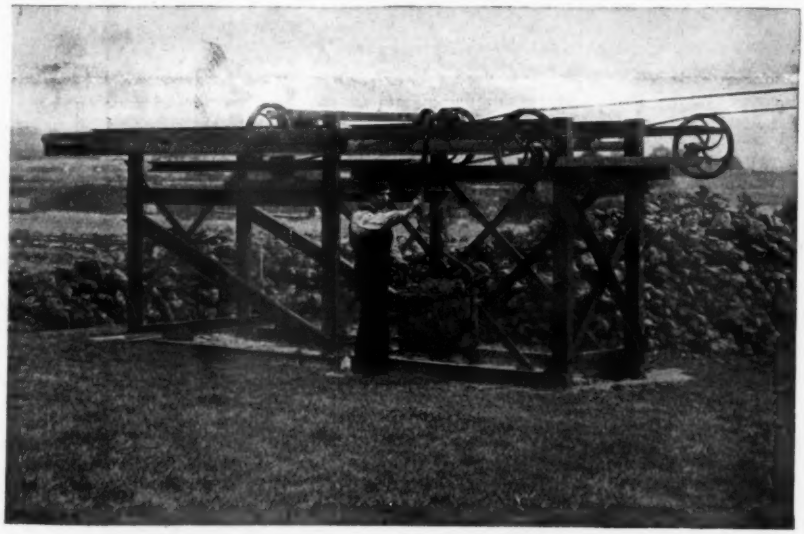


FIG. 1.—THE LOADING TERMINAL.

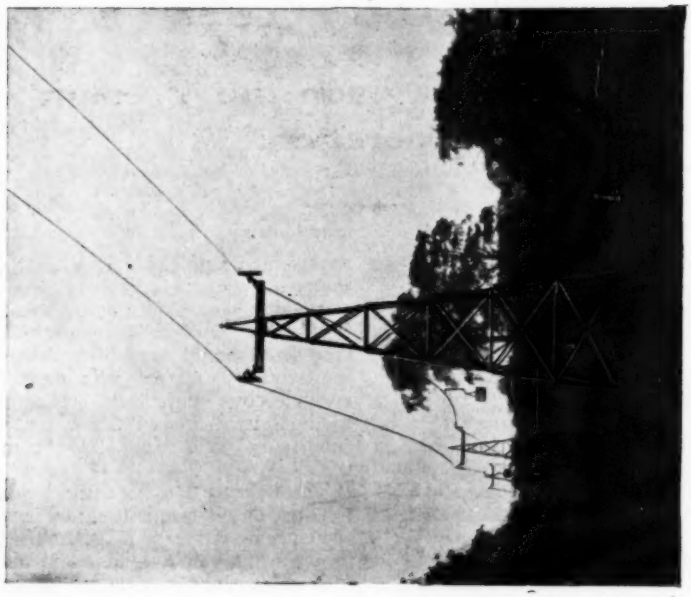


FIG. 3.—PART OF THE LINE SHOWING TYPE OF TRESTLE USED.

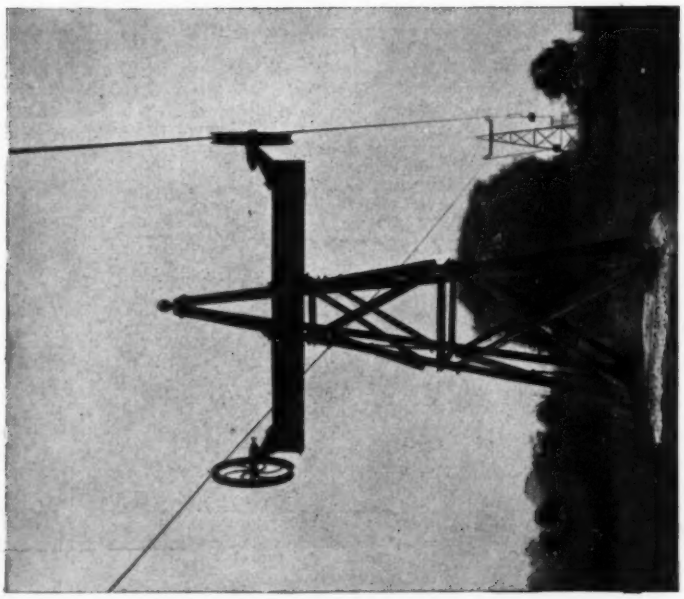


FIG. 2.—ONE OF THE TRESTLES IMMEDIATELY IN ADVANCE OF THE LOADING TERMINAL.

FIG. 4.—VIEW OF THE BRIDGE SCREEN.

addition of extra buckets, as at present the buckets are spaced a great distance apart.

Fig. 1 shows the loading terminal. This is constructed of steel and is entirely self-contained. It was so designed to enable the corporation to lower it into the ground, as the work of excavation proceeded, without causing any material alteration in the arrangement of the line.

Fig. 2 shows one of the trestles immediately in advance of the loading terminal. This is 10 ft. in height and can be easily lowered with the loading terminal if desired.

In order to meet the requirements of the byelaws, the bridge screen, shown in Fig. 4 had to be erected where the ropeway passes over the main road to catch any clay which might drop from the loaded buckets when passing over. The screen, which crosses the road diagonally, consists of two bow string girders supported on two light columns connected together at the top by lattice girders which support a short trestle.

Fig. 3 shows a part of the line, and illustrates the type of trestle adopted.

Fig. 5 shows the discharging terminal. This had to be built upon the bank of Alston Reservoir. The illustration shows the back end of the shunt rail with a carrier hanging therefrom ready to be tipped into the trucks which deposit the clay round the reservoir, and also shows the gear and the outside of the engine house. The driving gear and tension gear are situated at the end of this line.

The construction of the ropeway will

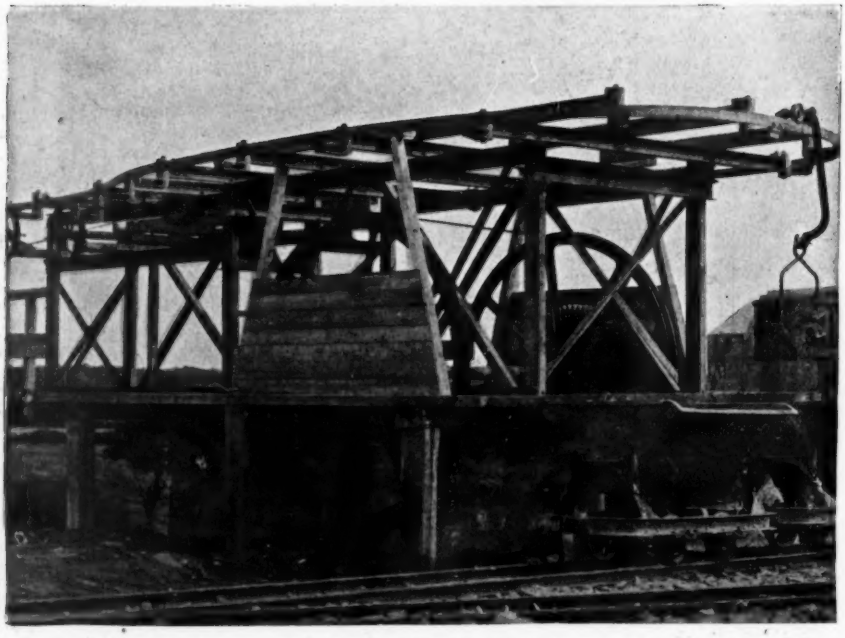


FIG. 5.—THE DISCHARGING TERMINAL.

effect a great saving in the cost of transporting the clay which would otherwise have had to be conveyed by motor lorries, a scheme which was abandoned owing to the cost and the damage which would have been done to the road, also owing to the protests of the residents of the district.

Motor Engineering.

By R. E. PHILLIPS, M.I.Mech.E., A.M.Inst.C.E.

The Society of Motor Manufacturers at Olympia.

The ninth annual exhibition of self-propelled road vehicles promoted by the Society of Motor Manufacturers has demonstrated in no unmeasured way that British manufacturers are fast making up the leeway resulting from restrictive legislation, and it can now be surely said that the motor car manufacturers of this country are producing vehicles which in no way fall short of the best productions of France and other foreign countries, and, what is of greater importance, the manufacture is being conducted on profitable lines. The balance sheets of the "Daimler," "Humber," "Darracq," "Argyll," "Swift," and other companies prove most conclusively that the manufacture of motor cars can now be carried out in this country not only at a profit, but at a very considerable profit. The profits made by some of these companies gives rise to the hope that the prices of cars will be materially reduced in the near future, and it is interesting to note that while some of these prosperous companies have not reduced, and in one case have even advanced, their prices for the coming season, others have reduced them as much as 20 per cent.

Notwithstanding the fact that commercial vehicles and boats have been relegated to a show of their own to be held next spring, the whole of the available space was occupied, and the stands of many of the larger manufacturers materially curtailed. Statistics show that three hundred and forty different models were exhibited, of which sixty-five were fitted with six-cylinder engines. The number of cars fitted with such engines was one of the features of the show, but the slavish adoption of such engines by some of the exhibitors was a matter more for regret than admiration, as their exhibits bore evidence of the haste with which they had been constructed to get them ready for the exhibition, and it is doubtful if more than 25 per cent. of the cars fitted with six cylinders were capable of being driven out of the building. Whilst admitting the superiority of the six-cylinder engine for powerful cars, we are at a loss to understand what material advantage is to be derived from the use of six cylinders in engines of 20 h.-p. and under, of which some examples were shown.

One of the most noticeable features of the show was the large number either of new firms embarking in the industry or of old-established firms taking up this particular branch of engineering.

Amongst the new firms exhibiting for the first time are the Austin Motor Co., Ltd., the Deasy Motor Car Manufacturing Co. Ltd., the Lindsay Motor Car Co., and the Pilgrim's Motor Car Co., and amongst established engineering firms taking up the manufacture of motor cars we notice the Britannia Co., Messrs. E. H. Bentall & Co., and the Westinghouse Co.

The most marked improvement in the 1907 models is the use of forced lubrication, while running this closely are the improvements in suspension, the increased accessibility to working parts, and the provisions made to make the cars dustless. The trend of design can best be followed by dealing seriatim with the component parts of the motor car. Taking the engine first:—The placing of all the valves on one side of the engine, thereby dispensing with one cam shaft and reducing the pocket area in the cylinder head, is now more generally followed. The practice of casting

cylinders in pairs is now more general than either of the alternatives of casting them singly or *en bloc*. Making the lower part of the crank chamber merely a lid capable of being removed for inspection purposes is now adopted on cars of any pretence to high class. This is a constructional detail that has everything to commend it, as anyone knows who has had to take out and take down an engine for the purpose of adjusting the big ends of connecting rods. The use of high tension magnetos appears to be on the increase to the exclusion of high tension ignition by accumulators and coils. The most interesting development of valve mechanism is the arrangement fitted by the Darracq Co. to give a lead to the mechanically operated inlet valves as the speed of the engine increases. This mechanism is coupled to the ignition control so as to be operated by the driver at the same time. This does not seem to us to be as good an arrangement as the auto-mechanical inlet valve which effects the same purpose automatically. Although the use of the atmospheric inlet valve seems to be a thing of the past, the use of the auto-mechanical inlet valve has not made such strides as its merits deserve. Only one firm—the Pilgrim's Way Motor Co.,—showed engines fitted with these valves, but as they have adopted it as their standard pattern, they, at all events, appreciate its good points. We described the application of this valve to the "Pilgrim" engine a short time back.

The use of a pump for drawing oil from a sump in the crank chamber and forcing it through all the bearings of the engine is increasing rapidly and is undoubtedly a step in the right direction, as it is only by some such automatic control that the smoky exhaust which makes automobiles so objectionable in the eyes of the public, can be obviated. Carburettors of the so-called automatic type do not seem to be making much headway, and if the Tourist Trophy Race has demonstated nothing else it has shown that the highest economy in fuel consumption can be obtained by controlling the air supply—or at least some portion of it—by hand. Several new carburettors were exhibited, which embodied novel features, notably those of Messrs. White and Poppe, the Swift Co., and Morgan & Co. As regards clutches, the old pattern cone clutch is more than holding its own, and makers are beginning to realise that a clutch of this type, if properly designed and constructed, leaves little to be desired, while it has the merit of extreme simplicity.

In change speed gears there is but little novelty, and although several developments of the epicyclic type of gear were in evidence there seems no reason to think it will ever supersede the other and more common type. With the advent of more powerful motors it was thought that the change speed gear would disappear, and one would have thought that it would have, at all events, rendered the use of a gear with a smaller number of velocity ratios possible, but instead of this we find nearly all the more powerful cars fitted with a four-speed gear and not a three. The use of the gate form of quadrant for the change speed lever is on the increase, and several very interesting modifications of it were exhibited, some of which quite successfully overcame the difficulty of imparting the lateral movement of the operating lever to get it through the neutral notch which has always been a difficult movement to effect. In transmission the propeller shaft drive still continues the fashion, and is now more largely used than the chain drive. This is undoubtedly due to the care and attention that has been directed to the construction both of the live back axle and the propeller shaft, but we doubt whether the propeller shaft drive would long retain the premier position if other makers of chain driven cars would follow the practice of the Sunbeam Co. and the C. G. V. Co. and fit dust-proof cases over the chains. Although the Sunbeam Co. have fitted their well-known oil-retaining case to the driving chains of their cars for some years back, we believe that Messrs. Charron Giradot and Voigt are the first French

firm to fit such cases, and as these two firms appear to have successfully overcome all the difficulties in the application of these cases it is more than probable that their use will become universal, when we anticipate the chain drive will again assert its claim to the premier position in transmission mechanism.

In bearings the tendency of present practice is to use balls everywhere, but we question the advisability of using them where the bearings are subjected to any kind of hammering action, and more than one manufacturer has attempted to introduce ball bearings to the big ends of connecting rods to his cost. We noticed that in several cases ball bearings designed to carry a load were also employed to take a thrust. It is such faults in design and construction as this that bring ball bearings into disrepute.

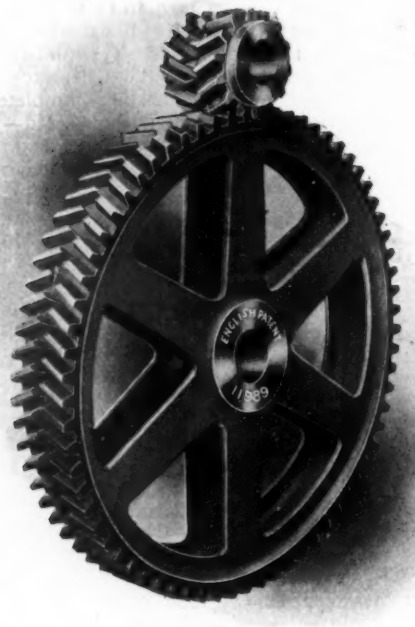
In frames the pressed steel type holds its own, and although more than one of the leading firms still adhere to the armoured wood type we think that there can be no doubt as to which is the best adapted for the work it is called upon to perform. Many firms are now using straight sided frames, the width throughout being sufficiently narrow to give the necessary look for the steering wheels. We noticed several frames raised up at the back. This may be a convenience in the design and construction of the chassis but it seems to us to materially enhance the work of the body builder. The springs are generally longer, wider, and more elastic, special attention apparently having been given to this part of the chassis. This use of transverse back springs is becoming very general, and in more than one case a front transverse spring is employed. In some of the larger cars the three-quarter elliptical spring is employed.

In wheels there is little development, and the metal wheel appears as far off as ever, though wheels with wire spokes built on the suspension principle have been largely used during the past season on cars constructed for speed purposes. In tyres many devices were shown to facilitate mounting and dismounting the tyre from the rim, and several wheels were shown with detachable rims whereby the tyre and rim can be removed from the wheel together, hereby enabling another complete rim and tyre—with the latter inflated—to be substituted for those removed. In view of the fact that the winners of the big motor races on the Continent during the past season have owed their success to the use of detachable rims and tyres, it was thought that there would have been a large number of such devices exhibited, but not only was this not so, but those that were shown leave much to be desired from a practical point of view.

In brakes, we are glad to note a decrease in the use of brakes of the expanding type, especially those used on the counter and propelling shafts. In our opinion, a properly designed and constructed band brake of the double grip type leaves little to be desired, and is certainly not liable to become choked with mud as are many of the internal expanding types. In the steering gear little advance has been made, and in no single instance has any attempt been made to construct a gear which will remain workable even should one of the material parts fail, in other words, to duplicate the essential parts. As regards bodies, all that can be said is that they are more luxurious than ever, and designed to make the motor car a vehicle of utility as well as of pleasure. Taken as a whole, no better exposition of the carriage builder's art has ever been seen.

Double Helical Wheels.

The Power Plant Co., Ltd., of Temple Bar House, Fleet Street, E.C., have taken up the manufacture of helical wheels under Würst's process of cutting, which insures such a high degree of accuracy that the defect of this type of wheel may now be said to be non-existent, and its merits are such that it should enter largely into motor car construction. By this improved method of



HELICAL WHEELS CUT BY THE WÜRST PROCESS

cutting the right and left hand teeth do not meet in the middle of the wheel but are staggered to the extent of half the pitch of the teeth, which produces the same effect as halving the pitch and doubling the number of teeth without the corresponding reduction in strength. Owing to the fact that the pinion and wheel do not come suddenly out of engagement as in straight toothed wheels but have a gradually increasing and decreasing engagement, they can be run at a velocity of 60 ft. per minute without danger, and, further, owing to the staggered arrangement of the teeth the total engagement between pinion and wheel is constant.

Steam Plant of the "White" Motor Car.

Last month we were able to give a full description of the steam plant of the "Clarkson" steam vehicle. As that of the "White" motor car forms an equally conspicuous example of what can be accomplished on a small scale in the use of steam of high pressure and with a high degree of superheat, a description of this plant will prove of considerable interest to all who are watching the application of steam to road vehicles. The 1907 model has recently been submitted to a thorough test by Mr. R. C. Carpenter, who presented a description of the engine, and the results of the tests to a meeting of the American Society of Mechanical Engineers.*

The steam generator or boiler of the "White" system is a series of horizontal coils connected so as to form a continuous tube through which all the water fed to the boiler and all the steam discharged from the boiler must pass. It is not provided with any reservoir either for water or steam. A perspective view of the boiler as used in the 1906 car is shown in Fig. 1 with the external casing removed. Its essential distinctive feature is due to the fact that the water is kept at the top and the steam at the bottom; it differs from all types of stationary boilers by the absence of a reservoir for steam. The construction of the boiler for the 18 brake horsepower engine which was used in the 1906 cars is essentially as follows, and is typical of all sizes; eleven helical coils of drawn steel tubing are joined in series and connected so as to produce a system of circulation of such a character that the water or steam, in order to pass from one coil to that next below, must rise to a level above the top coil before it can pass down again. Fig. 1 shows

* Proceedings of the American Society Mechanical Engineers. Vol. xxviii., December, 1906.

the external view of the connections referred to, which pass from the external circumference of the coil upward to a point above the level of the top coil and thence downward in the central space, where it joins the coil of a lower level. Tubing having a nominal internal diameter of $\frac{3}{4}$ inch was used in the boilers of 1904–05 and 1906 and of $\frac{1}{2}$ inch in the new boiler recently built for the 1907 car.* The joints connecting the various coils are, it is noted, located in an accessible position. This construction makes it possible to maintain water in the upper portion of the boiler and steam in the lower. It prevents the water from descending by gravity and renders the circulation through the generator dependent upon the action of the pumps which supply the boiler with water. The general direction of circulation of the water and steam is the reverse of that of the products of combustion.

The "White" boiler has frequently been classified as a flash or semi-flash boiler; whether this classification is correct or not depends upon the definition of the term "flash boiler." In the flash boiler, water is suddenly converted into steam by contact with a very hot metal surface and in the operation of such a boiler the metallic surface with which the steam is brought in contact is maintained at a much higher temperature than that of the steam. The "White" boiler, as noted from the description, always contains a considerable amount of water which is forced downward and over the heating surfaces at a rate proportional to the demand for steam, and under its normal mode of operation it is doubtful if the metallic surfaces have much or any higher temperature than that of the steam which they contain. The name "Continuous Flow or Single Tube Boiler" would better describe the class to which the "White" boiler belongs than the term "flash."

The diameter of each pressure element is small and consequently of great strength and not likely to be strained to any high percentage of its ultimate strength by any pressure which could be produced under ordinary conditions.* The high working pressure gives great power to the engine and explains the great success of the car in climbing high hills and in passing over unusually bad roads. A safety valve is attached which may be set at any desired pressure but is usually set to blow off at from 1,000 to 1,200 lbs. per sq. in. Because of the small quantity of water and steam present in the boiler, no serious damage is probable to person or property, even should the boiler tube be accidentally split or ruptured as the effect would be simply that of allowing the steam to gradually escape without producing any disastrous results, and even this accident has been extremely rare. Considering the fact that thousands of these steam generators are in use, in the charge of men who have had practically no experience in the operation of steam plants, the results as to freedom from accident are remarkable, and indicate that the apparatus is from the standpoint of safety not open to criticism.

The author tried to get data respecting the amount of deposit of scale in the tube of the "White" boiler due to its continued use, but without any great degree of success. Investigation indicates that there has been very little practical difficulty due to this deposit, and the makers report only a few instances which have come to their knowledge of any trouble due to this cause. The velocity of discharge of steam through the single tube of the boiler is great, and it is believed has been sufficient to remove the deposits in nearly every case. In the boiler as much as 488 lbs. of steam were provided per hour by the one-half inch tube. Without taking into account the extra volume produced by superheat, the calculated velocity approximates 400 ft. per second through the tube. Because

* The actual dimensions of tubing used in the "White" boiler are as follows: E and F boiler (1905—06), internal diameter 0·372 in., outside diameter 0·535 in; G boiler (1907), internal diameter 0·540 in., outside diameter 0·72 in.

* The strength of the fittings at the point of leakage for the tubing was found to vary from 7,000 to 18,000 lbs. per sq. in.

of increased volume due to the high degree of superheat the actual velocity approximates one-third more.

For the actual operation of the boiler on the car, water is taken from a reservoir which is supplied in great part with water condensed in an air surface condenser. The condenser is located at the front of the car, and receives the exhaust from the engine which contains an appreciable amount of cylinder oil. A large proportion of this oil remains in the water tank and is discharged when convenient, but at times quite a considerable amount is forced through the boiler. So far as the makers have been able to ascertain, no injurious effects have been caused by this practice, and as a consequence, they have made no attempts to introduce a separator for removing this oil.

The furnace or burner which is employed with the steam generator for use on motor cars is shown at *P*, Fig. 1, located beneath the boiler and adapted for the burning of gasolene vapour. The figure also shows the various means of automatic control of fuel and water which are employed with the generator. While burners of other types adapted for other fuels than gasolene can and doubtless will be used when conditions demand it, the gasolene burner employed has proved very efficient. In the burning of gasolene a vapour must first be produced by heat or other means which must be mixed with air previous to the combustion in order to give perfect results and high efficiency; for this reason all gasolene burners are provided with means for vaporising the gasolene before it is fed to the furnace, which usually consists of means for heating, termed a *vaporiser*, as is shown at *O*, Fig. 1. The burner consists of a cast iron grate with slotted openings shown at *P*, with a sheet metal chamber underneath closed except where pipes enter for admission of air as shown at *M*. In the 1905 car, the air pipes were directed radially into the chamber below the burner. In the 1906 car the air pipes direct the entering air tangentially, as shown in Fig. 1. The change in the direction of the air pipes has resulted in a decided reduction of noise and an increase of capacity and efficiency of the burner. For the 1907 car the air pipe is supplied with a regulating valve. The gasolene is supplied through a pipe and flows past a valve *D* which is operated by a thermostat; it then flows into the vaporiser *O*, where it is heated; thence it flows to the centre of the air pipe *M*.

The thermostat shown at *Y* in Fig. 1, and in detail in Fig. 2, consists of a rod inserted into the steam pipe so as to be in contact with the steam on its passage from the boiler to the engine. The expansion of this rod controls the gasolene valve at *D*, Fig. 1, and at *F*, Fig. 2. The thermostat is ordinarily adjusted so that the oil supply valve will remain open until the temperature of the steam rises to about 800° F. In order to light and relight the main burner when necessary a small gasolene flame called a pilot flame, shown at *C*, Fig. 1, is kept burning constantly during the time the vehicle is in use. The valves for the hand control of the gasolene supply are shown at *L*, Fig. 1. In the operation of the burner the gasolene is discharged with considerable velocity, and while in a vaporised condition into the air pipe *M*, Fig. 1, and by this operation draws in a sufficient amount of air for supporting combustion, which is mixed with the gasolene vapour and burns with a hot flame on top of the cast iron grating.

For the purpose of use on the motor-car it is also desirable to have an automatic control of the supply of water; this is obtained in the "White" car by means of a pump which is directly connected to the engine and which may deliver water either directly into the boiler or into the source of supply, depending upon the opening of a valve controlled by the steam pressure acting against a spring, as shown in section in Fig. 3. If the pressure rises above 400 lbs. or to any desired amount, the valve *P* is opened so as to return the water through the opening *Q* to the source of supply. If, on the other hand, the pressure is

below the required amount, the valve is closed by the tension of the spring and is forced by the pump into the boiler.

It is noted by Fig. 1. that no water gauge is supplied to the boiler and from the description of its operation it is seen that none is necessary.

The water circulating system is shown in Fig. 4, the generator being at the extreme right hand, the condenser at the extreme left, with the various pumps and pipe connections intermediate. The water tank or reservoir is shown at *27*A, the two feed pumps are at *23*. These pumps are mechanically connected to the engine and take water from the reservoir *27*A, and deliver this water either into the generator or into the source of supply, depending upon whether the by-pass valve with which both deliveries are provided are open or closed. The by-pass of one pump is controlled by hand by the valve *28*A, and of the other pump by the pressure regulator which is located at *9* and has been fully described. A hand pump is provided at *17*A which may be used to fill the generator when the engine is not running. The water is taken from the lower portion of the condenser through the pipe *34*, by vacuum air pump *19*A, and delivered to the reservoir. This pump is also kept in continuous operation by direct connection to the engine.

In the operation of the plant as applied to a steam car and provided with the automatic devices as described, the fuel and water are supplied as the demand for steam requires, with scarcely any attention on the part of the

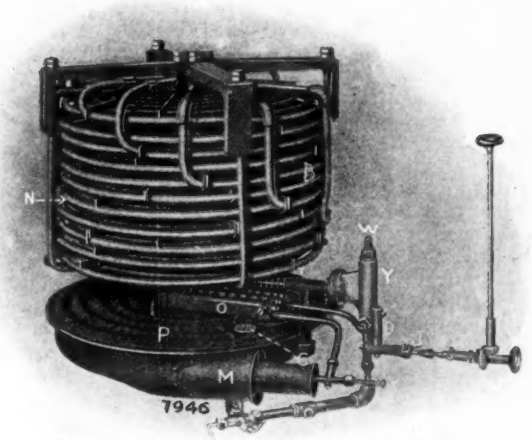


FIG. 1.—THE "WHITE" GENERATOR, SHOWING ALSO THE BURNER, VAPORISER, PILOT LIGHT AND GASOLENE CONNECTIONS, WITH EXTERNAL CASING REMOVED.

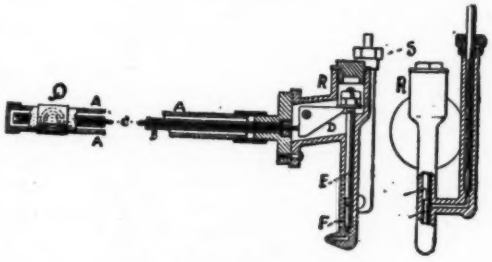


FIG. 2.—DETAILS OF THERMOSTAT.

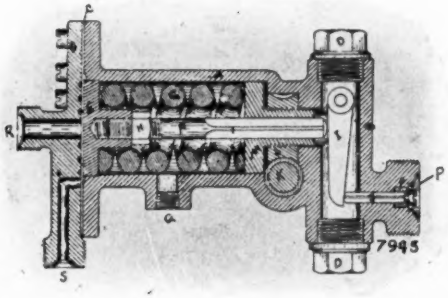


FIG. 3.—WATER REGULATOR.

operator. Thus, for instance, if the steam pressure becomes excessive, the water supply is closed off by the water regulator, Fig. 3, which immediately causes the pressure to drop. If the temperature of the steam becomes excessive, which would soon be the case if the water supply were turned off, the fuel supply is cut off by the thermostat, Fig. 2, which soon reduces the temperature to the normal amount. On the other hand, if there is an excessive amount of steam drawn off, the pressure and temperature would change in the reverse direction, which would cause the automatic devices to turn on a supply of fuel and water to meet the demand.

For the purposes of meeting an extraordinary demand for power which sometimes happens in ascending a long hill, an auxiliary pump already referred to is kept in constant operation by the engine, the discharge of which can be made to go either into the boiler or into the source of supply by opening or closing a valve by hand, which is located convenient to the operator. It is noted from this description that the operation of the "White" system is very different from that of the ordinary steam plant, and that the operator has little more to do than to control the motions of the engine, the steam generator providing steam when required. As used in the steam car the pressure is likely to fluctuate through wide ranges, for the reason that it will vary directly in accordance with the demand. The generator will supply high pressure steam when a large amount of power is required and steam of low pressure when but little power is needed.

The engine of the "White" steam car, as constructed for the 1907 car, is a vertical cross compound with piston valve on the high pressure and a plain slide valve on the low and which, except for its good workmanship, has no special points of merit. It is provided with ball bearings throughout so as to render the mechanical friction as small as possible. The cranks are set quartering so that the engine as a whole has no dead centre. It is provided with a simple device under the control of the foot of the operator which will admit high pressure steam into the low pressure cylinder when necessary either for the purposes of starting or for obtaining a large amount of power for use in an emergency. The valves are driven from double eccentrics through the medium of "Stephenson" links and are operated in essentially the same manner as those in use in the ordinary steam locomotive, *i.e.*, the point of cut-off can be changed and the engine reversed by a movement of the link. A view partly in section of the engine is shown in Fig. 5, which will be readily understood without further explanation.

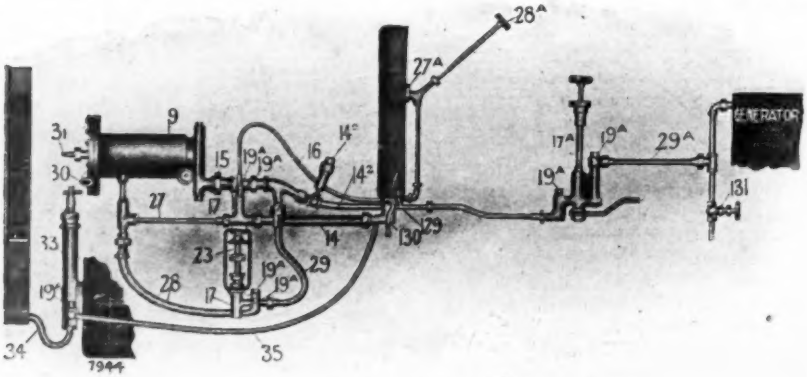


FIG. 4.—WATER CIRCULATION SYSTEM.

The engine is directly connected to various pumps already referred to which consist (1) of an air pump that is used to maintain an air pressure on the fuel tank for the purpose of regulating the feed of oil to the boiler, shown at *P*, (2) a vacuum air pump shown at *R*, also two boiler feed pumps shown at *I* and *S*. The one shown at *T* is provided with a by-pass controlled by the steam pressure as described, the other shown at *S*, with a by-pass controlled by hand. These pumps are simple plunger pumps with practically no mechanism to get out of order.

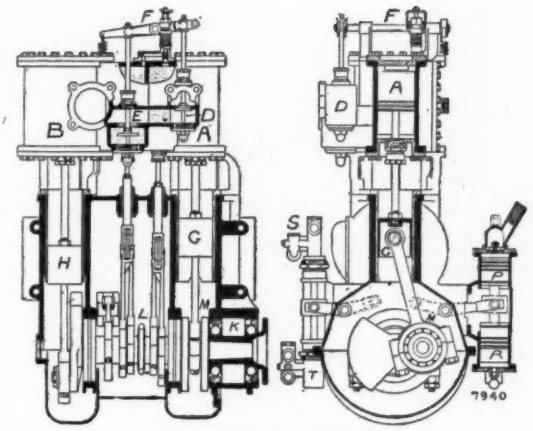


FIG. 5.—SECTION THROUGH ENGINE.

The steam system is provided with an air condenser which in its application to a motor car is placed at the front of the vehicle. It consists of a series of corrugated copper pipes with suitable header connections at top and bottom and is arranged to receive the exhaust steam into the upper header.* The condensed water falls by gravity to the lower header and is removed by a pump. The tubes are surrounded by air, which is circulated by the motion of the vehicle supplemented by the use of a fan located between the engine and the condensing surface. The condenser is furnished with a relief valve which opens to exhaust steam into the air in case the back pressure becomes of sensible amount. The condenser as previously applied to motor cars was not adapted to produce a sensible vacuum, its purpose being to conserve the water supply.

Recent improvements in the pumping system give a substantial vacuum from which a considerable increase in economy due to the vacuum is anticipated in the

* The condenser dimensions are as follows:—For E and F cars (1905—6) 74 tubes, 24·5 ins. long, with a total surface of 118 sq. ft. For car (1907) of 65 tubes 27 ins. long with a total surface of 136 sq. ft.

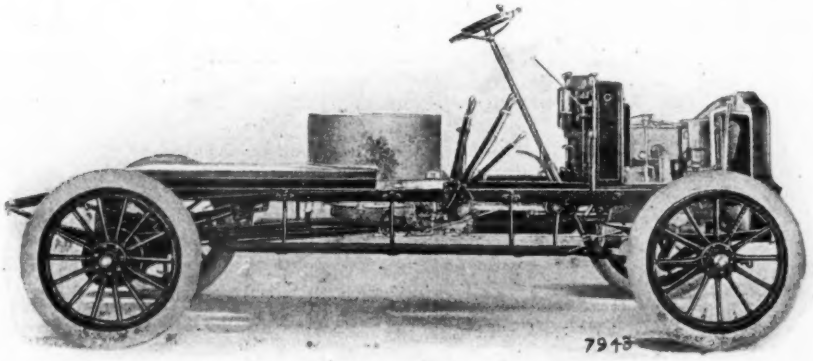


FIG. 6.—THE CHASSIS.

future. The motor car of 1907, it is expected, will maintain a vacuum of over ten inches at a speed of 20 miles per hour.

The arrangement of the power plant as applied to a motor car, is not especially pertinent to this article but being of considerable general interest is shown in the accompanying view of the chassis, Fig. 6, in relation to the supporting framework and the propelling wheels. The boiler occupies a position somewhat back of the centre of the frame and discharges the products of combustion downward and to the rear; the condenser occupies a position at the extreme front, the engine a position just back of the condenser, and the water tank a position just in the rear of the engine. When the body of the vehicle is in position the forward seat is located directly over the boiler and an ornamental hood is placed over the engine and the space between the water tank and condenser. The throttle valve of the engine is controlled by the small hand wheel located above the steering wheel.

The engine is connected to the rear axle by a shaft drive which is provided with a clutch and one change gear, making it possible to operate the engine independently of the vehicle and also to vary the ratio of speed of crank shaft and rear axle. The car is provided with a double set of brakes, a steering gear controlling levers for the engine, and a complete equipment of force feed lubricators, which need no consideration in this article.

In the usual operation of the car, the operator does little more than to steer and open or close the throttle as more or less speed is required. The automatic devices take care of the steam supply except for extraordinary conditions where an unusual amount of power is required; for such cases hand control of the water supply must be employed.

The engine is operated with steam superheated about 300° under usual

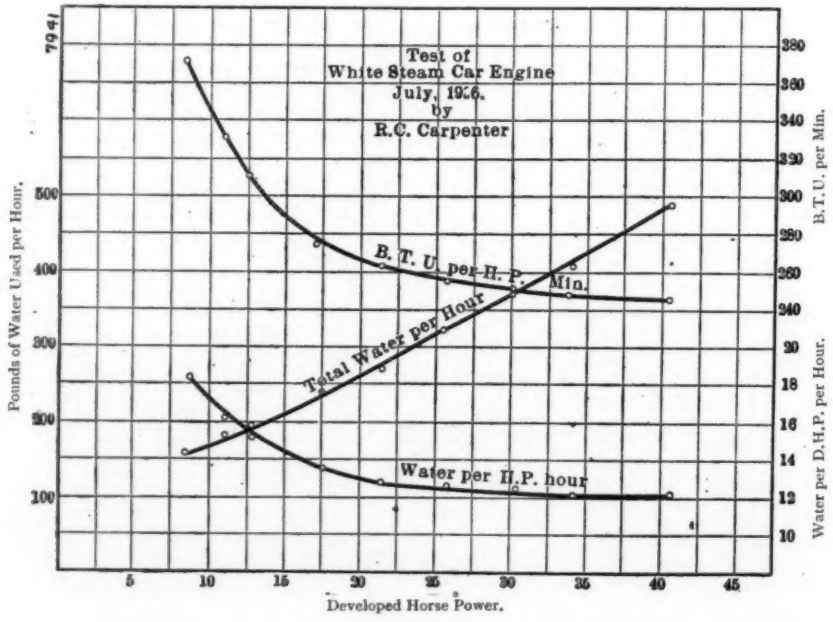


FIG. 7.

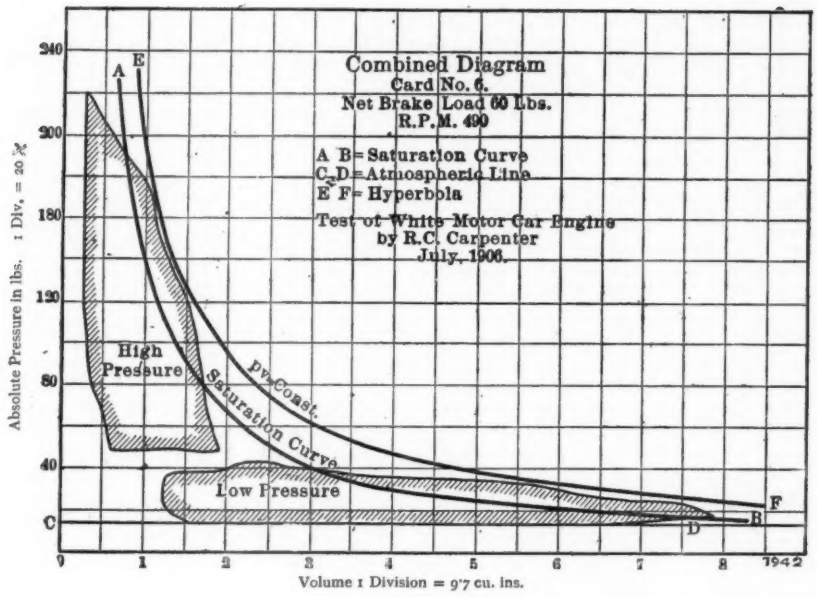


FIG. 8

conditions of operation, and under such conditions the steam system has shown a high economy.

Prof. C. H. Benjamin, of the Case School of Applied Science, Cleveland, Ohio, made a very careful brake test of the steam plant of the "White" system of 1903 which used a 10 h.-p. engine and found that when the engine was fully loaded it used only 12·6 pounds of steam per brake h.-p. hour and 1·16 pounds of gasolene per h.-p. hour. These results are unprecedented for small steam plants of any size and are nearly equal to the best results obtained with large triple expansion condensing engines.

The author conducted a test of the boiler and engine for the 1907 car from July 9 to 17, 1906.

The engine and boiler having essentially the same features of design as those previously used, but are somewhat larger and have increased power. The engine used in the "White" steam cars of 1905 and 1906 had cylinders 3 and 5 ins. in diameter by $3\frac{1}{2}$ ins. stroke, and was rated at 18 h.-p. The one tested had cylinders 3 and 6 ins. diameter by $4\frac{1}{2}$ ins. stroke, and is rated by the company at 30 h.-p.

Dimensions of Engine for 1907 car:

Diameter of cylinders, 3 ins. high pressure, 6 ins. low pressure.

Diameter of piston rods, $\frac{9}{16}$ in. high, $\frac{9}{16}$ in. low.

Clearance of engine, 17·9 per cent. high, 19·3 per cent. low.

Weight of cylinder castings with guides, 98·5 lbs.

Weight of engine frame complete, 201·5 lbs.

Weight of valves and fittings, 28·0 lbs.

Total weight, engine complete, 328 lbs.

The boiler consists of nine coils of drawn tubing with a nominal internal diameter of $\frac{1}{2}$ in., actual internal diameter of 0·53 in., actual external diameter 0·72 in. The external diameter of the boiler is 22 ins.; its height, 11 ins. The boiler contains 243 ft. in length of $\frac{1}{4}$ in. tubing, and has a heating surface which

is calculated as amounting to about 45·8 sq. ft.

The weight of the boiler without fittings is 150 lbs. The weight of casing, bolts, and all the fittings is 125 lbs. additional, making the total weight of the boiler complete as 275 lbs. The weight of burner is 40 lbs. From this it is noted that the total weight of the power system is about 643 lbs. The maximum brake horse power, as shown on the test, is about 45, hence the weight is about 14·3 lbs. per D.H.P.

Tables given in the original paper show that during the various brake tests of pressures, temperatures, and degrees of super-heat, the boiler pressure averaged 595 lbs., the steam chest pressure varied with the load from 152 lbs. to 427 lbs., averaging 303 lbs. The temperature of the steam near the boiler averaged 783° F., that in the steam chest 757° F. This indicates that the steam leaving the boiler was superheated nearly 300°, that entering the steam chest about 340°, and that exhausted about 28°, so that the steam in its entire passage through the engine remained in a superheated condition.

The principal economic results of these tables are shown on the diagram, Fig. 7, in relation to the total developed horse-power, from which it is noted that with the exception of the light loads the diagram representing the total weight of steam in relation to the total developed horse-power is a straight line. At light loads the line curves slightly upward and away from the straight line. The economic results at very light loads could not be obtained because of the friction of the brake even when the water pressure was off.

The results of the indicator tests are tabulated in the original paper. These results indicate that the work lost in friction at about 460 revolutions per minute averages 1·45 h.-p.

A combined diagram of several indicator cards is shown in Fig. 8, on which a curve showing the volume of the same weight of saturated steam is indicated by a dotted line. This line shows that the steam was slightly superheated from cut-off to release in the high pressure cylinder and considerably superheated throughout the low pressure cylinder, and that there was no shrinkage of volume in either cylinder due to condensation.

The average pressure of steam at the boiler during the various runs was 595 lbs. The average degree of superheat at the boiler was 298°. The mean temperature of feed water was 78°. The average evaporation was 10·34 lbs. of water for 1 lb. of gasolene.

From this data, by Buel's steam tables, we find:—

B.T.U. per pound of steam above 212° =	1,051
B.T.U. „ for raising feed to 212° =	144
Specific heat = 0·69	
Heat required to superheat 298° = 298 × 69 ... ... =	206
Total	1,401

Equivalent evaporation from and at 212° per sq. ft. of heating surface per hour was 13 lbs. for highest result.

The engine developed a horse-power on the brake at its highest load during the various tests with a consumption of 11·96 lbs. of feed water per hour. The evaporation under actual running conditions with the feed water heater in operation was 11·5 lbs. of water for one of gasolene. This would show that 1·04 lbs. of gasolene would be used under best conditions per developed horse-power.

Electrical Engineering Notes.

By ANDREW STEWART, A.M.I.E.E.

Electric Power from the Victoria Falls.

We have already dealt at some length with the engineering and commercial aspects of this scheme,* but its sudden resuscitation in the columns of the daily press has awakened widespread interest, chiefly on account of the important features which are now revealed, for, not content with harnessing the Victoria Falls, the promoters must construct a second edition of these falls at the Transvaal end of the transmission line.

The magnitude of the latter will be gauged from the fact that it is proposed to make the artificial waterfall capable of supplying the demand for power, for twelve hours, should the supply from the Victoria Falls be interrupted. Doubtful as the scheme always appeared, it cannot be said that its prospects have been improved by the latest proposals, for notwithstanding the number of eminent engineers who have consented to stand godfather to the scheme, it does not seem clear that any have staked much on the *commercial* success of the undertaking.

A scheme which involves harnessing the Zambesi Falls to the extent of 50,000 h.-p., and transmitting some portion of that power over 700 miles of overhead line, is ambitious enough, in view of the fact that the longest transmission line now in use is just about 400 miles, and then the power delivered has in that case, the easy task of competing with coal at about 35*s.* per ton, whereas the South African scheme must face the competition of coal at 11*s.* to 12*s.* per ton, so that while the longer transmission in the case of the South African scheme involves much more capital, the market value of the power when delivered on the Rand, will be less, hence the proposal would want very careful examination before much money is spent on it.

When, however, the foregoing scheme is coupled with a supplementary Fall in the Transvaal which has two reservoirs, one 600 feet above the other, and capable of holding water enough to meet the demand for power for twelve hours, should the main supply be interrupted, and in case interruption should last for more than this period, a steam station having a like capacity, is also to be erected, the scheme becomes more than ambitious. Such is the scheme as outlined in the *Times* and subsequently elaborated with the ingenuity which characterised the now famous advertisements of the Encyclopedia Britannica. Whether with the object of preparing the public mind for the inevitable prospectus or not, one cannot say, but the advertising skill is to be admired.

The hydraulic accumulator system is interesting if nothing else, for during the hours of light load the energy transmitted is to drive huge electrically driven pumps which will raise water from the lower to the upper reservoir where, should necessity arise, it will flow down to the low level once more, and drive turbine driven dynamos to take the load.

With two reservoirs, each having a capacity of several million gallons of water, with the necessary dams, pumps, turbines, generators, and so on, to say nothing of the supply of make up water in a country where the evaporation is 72 inches per annum, and the Water Board charge about 3*s.* 6*d.* per thousand gallons—what this will represent in capital and maintenance expenses, the promoters either do not know, or if they do, they have not sufficient courage to

* See THE ENGINEERING REVIEW, February, 1906, page 145.

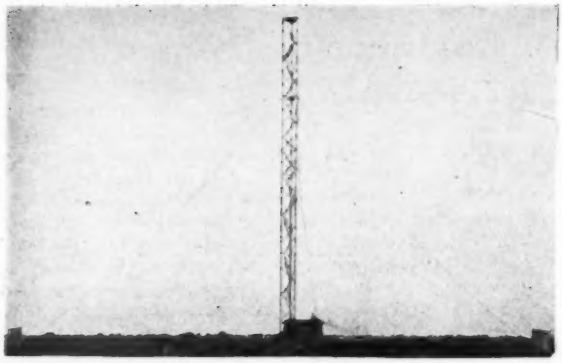


FIG. 1.

tell the engineering public. Capital charges alone will represent a few thousand pounds per annum and it is just possible that this standby plant will not be used once in a year.

Should, however, the transmission line fail, and this costly hydraulic accumulator become bankrupt in twelve hours, as it would do if the line were not repaired within that time, they will fall back on a steam plant, which will also be erected close to the Rand. This involves a further capital investment of say £300,000, which would lie idle unless the supply from the Victoria Falls were interrupted for more than twelve hours, and might easily prove a continuous burden except for an hour or two in a decade; indeed, if the opinons of the experts on the continuity of the service are of any value there is little prospect of this steam station eyer being more than a financial burden that has scarcely the merit of insurance against total cessation of supply to recommend it. The promoters make much of the fact that they have secured the best engineering talent it is possible to obtain. There is no doubt that, given sufficient capital, the scheme can be brought to a successful issue; but why spend five or six million pounds on a scheme of that kind when for about one and-a-half millions a steam or gas driven plant can be built on the spot? Coal is not such a serious item as Mr. Wilson Fox would have us believe, for as pointed out by us a year ago, it can be obtained on the Rand for 11*s.* per ton; if this is so, a gas engine will give a unit for not over ·135*d.*, and a steam engine for ·270*d.*, while the difference between the capital required for the Victoria Falls scheme and a steam or gas station on the spot, represents at four per cent. per annum and on an output of 88 million units per annum, ·375*d.* per unit, so that there is apparently no justification for going to Victoria Falls at all.

With regard to the alleged eagerness of German banks and industrial undertakings to take up the scheme, British banks and British manufacturers can get plenty of more promising outlets for their capital, though we suspect that if any British banker is misguided enough to offer financial support he will be welcomed; indeed, promoters do not usually spend money on two column advertisements in the *Times* if it is not with the object of interesting its readers in the matter; that this appears to be the object is clear from the remark of the manager of the British South Africa Company during an interview in the *Daily Telegraph* where he states that, no one with a spark of imagination could fail to be enthralled if he allows his mind to dwell upon the fascinating possibilities of this great enterprise. We trust that we possess more than a spark of imagination,

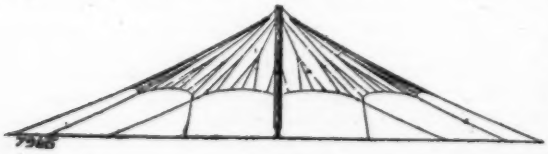


FIG. 2.

but even then, we are unable to imagine where the profits will come from.

A New Product from the Electric Furnace.

The use of carborundum is so universal that engineers will be interested in an abrasive of a somewhat similar nature, viz., alundum, which is being produced by the Norton Company, of Worcester, Massachusets. The raw material is purified bauxite, well enough known in the production of aluminium. This material is melted at a temperature of 6,000 to 7,000° F. in the electric furnace, in a homogeneous bath, and when cooled it crystallises into a solid mass, which is crushed to small pieces and sifted and graded.

This new abrasive is almost as hard as a diamond, and is being rapidly adopted in place of carborundum for many purposes. The Norton Company have eleven furnaces working and produce about 30 tons of the material per day of twenty-four hours.

Some Developments of Wireless Telegraphy.

Telegraphy without wires involves engineering considerations undreamt of a few years ago, and the wireless telegraph station recently completed in the vicinity of Berlin, for the purpose of communicating with the various European wireless telegraph stations, and also with ships crossing the Atlantic, demands some attention if only on account of the extraordinary height of the iron mast and the methods adopted in supporting it. The station has been constructed by the German Wireless Telegraph Company, who have a good deal of experience with work of a similar nature, and consists of an iron mast, Fig. 1, with a building of two floors at the base, containing an operating room and a sleeping apartment on the ground floor, and an upper floor, Fig. 3, devoted to the Leyden jars, spark gap, and similar apparatus.

The engine is housed in a lean-to, seen on the left of the building, Fig. 1;

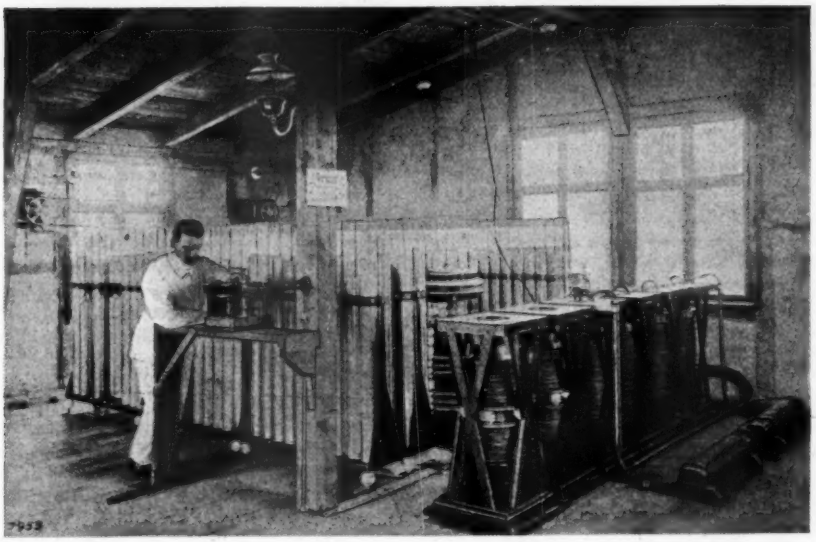


FIG. 3.—INTERIOR OF OPERATING ROOM, SHOWING INDUCTION COILS.

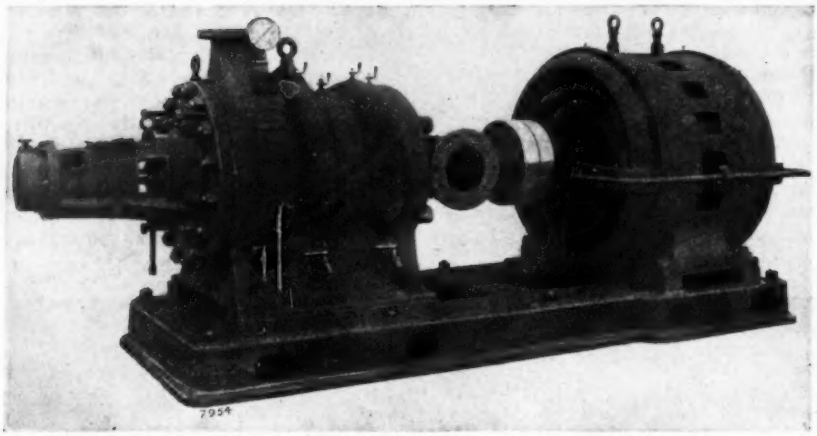


FIG. 4.—MOTOR-DRIVEN SIX-STAGE CENTRIFUGAL PUMP AT THE MERKUR SHAFT OF THE EMS MINES.

it is of 36 h.-p. and drives a 25 kilowatt single-phase alternating current generator, which when working up to its full capacity through the induction coil, which has a battery of Leyden jars in parallel with the secondary, gives a spark 3¼ ft. long.

The mast is a triangular section lattice girder 327 ft. long, terminating at its lower end in a cast steel sphere, which rests in a socket built into a concrete foundation. It is thus resting in a ball and socket joint and depends for support on stays, barely discernible in the photograph. These stays are attached to the tower at a height of 246 ft. and attached to three anchorages 660 ft. from the foundations of the tower.

A stair inside the tower gives access to the aerial which takes the form of an umbrella having three sets of antennæ (see Fig. 2), which are located so as to balance each other ; the upper ends are fixed to the mast by oil insulators, and from here the connecting wires are led down the mast to the operating station at the foot.

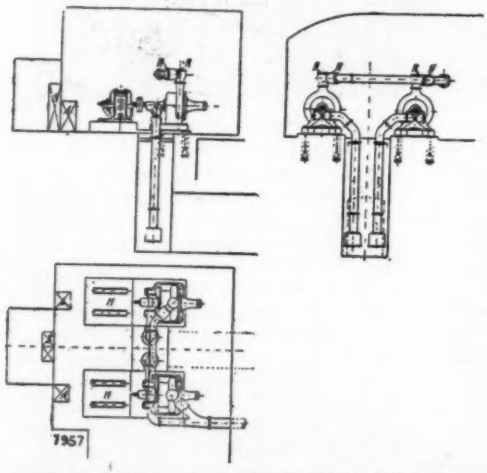


FIG. 5.—ARRANGEMENT OF PUMPS AT THE ST. MARIE MINE, MALTIERRES.

Multi-Stage Turbine Pumps in German Collieries.

The use of turbine pumps instead of the familiar ram pump for mine drainage is spreading quite as rapidly on the continent of Europe as in this country. Fig. 4 shows a six stage "Sulzer" pump driven by a 200 h.-p. electric motor capable of delivering 560 gallons per minute against a head of 850 ft. The pump and its motor

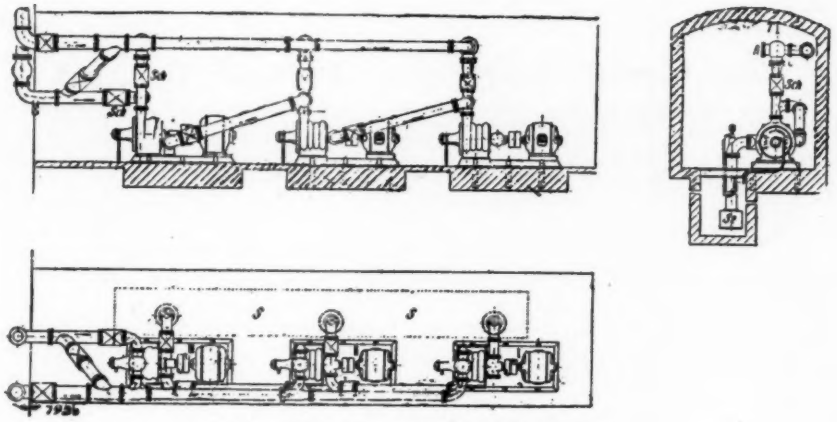


FIG. 6.—TURBINE PUMPS IN SERIES FOR MINE DRAINAGE.

runs at 1,455 revolutions per minute and is installed in the Ems Mine.

Another interesting plant is installed at the St. Marie mine, Maizieres, where similar pumps are used to drain the mine. They run at 960 revolutions and deliver 1,500 gallons per minute against a head of 490 ft. As will be seen from the drawing, Fig. 5, they draw from a common sump and deliver into a common discharge.

At another mine similar pumps are employed delivering 660 gallons per minute against a head of 2,150 ft. In this case the pumps are in series after the manner shown in Fig. 6. One pump draws from the sump and delivers to its neighbour, though for delivering to a lesser height all that is necessary is to open the valves on the suction and close the delivery from the other pump, this being allowed to discharge into the delivery pipe. In other cases one large electric motor with a pump on either side has been employed, the two pumps being in series. Tests show efficiencies of the order of 73 to 75 per cent. for these outfits, when working on full load.

The Great Northern, Piccadilly and Brompton Railway.

THE past month has been rendered important to Londoners by the completion and opening of that important line of tube construction, known as the Great Northern, Piccadilly and Brompton Railway, which forms a further step towards the realisation of the complete scheme formulated by the Underground Electric Railway Company of London some years ago.

This scheme involved the electrification of the Metropolitan District Railway and the construction of three tube railways, namely, the Baker Street and Waterloo; that now under review; and the Charing Cross, Euston and Hampstead Railways, now under construction; all of which are supplied with electric energy from the central generating station at Lot's Road, Chelsea, also belonging to the Underground Electric Railway Company.

By midsummer next it is expected that the remaining line will be completed, thus providing a network with such interconnecting facilities, as to render travelling in the metropolis both speedy and comfortable.

The accompanying map shows, at a glance, the chief areas and points of interest served by the new lines, and the interconnections between the principal railway termini and electric rail and tramways.

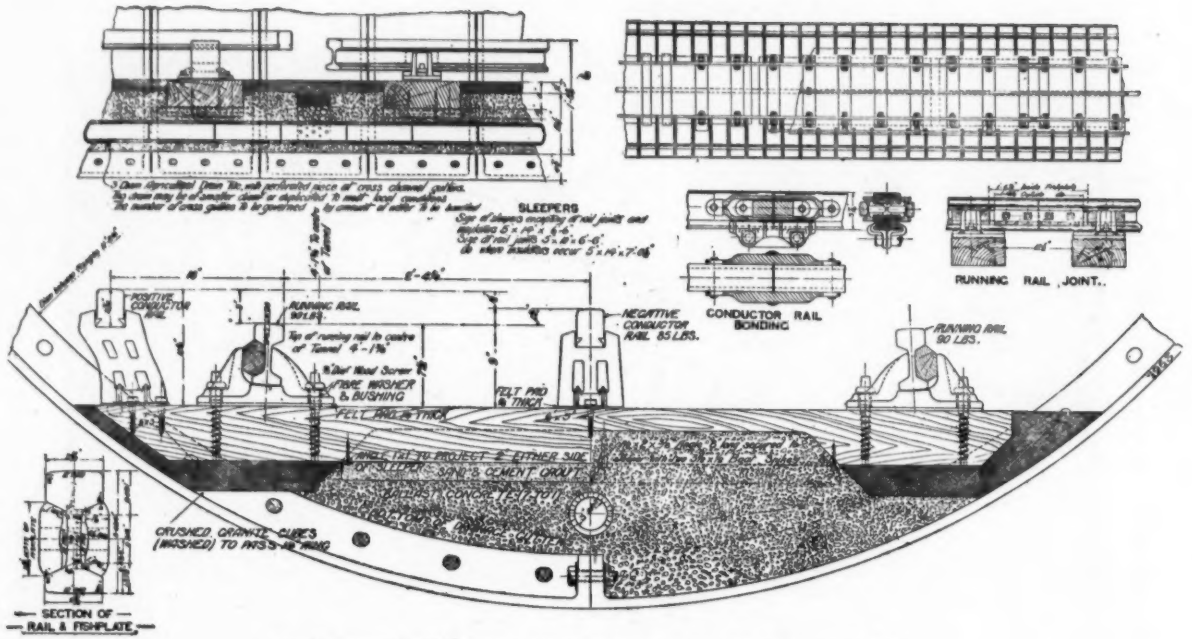
The history of the undertaking commenced with the incorporation of the Brompton and Piccadilly Circus Railway Company by the Brompton and Piccadilly Circus Railway Act, 1897, with powers to make a comparatively short underground electric railway between the places named. Further powers were conferred by subsequent Acts. In 1899 the Great Northern and Strand Railway Company was incorporated by an Act with powers to construct an underground electric railway from Finsbury Park to the Strand. In 1902 a Brompton and Piccadilly Circus Railway Act and a Great Northern and Strand Railway Act were passed through Parliament, under which the powers were merged, and authority was given for the extension of the Brompton and Piccadilly Circus Railway, from the circus named to a junction with the Great Northern and Strand Railway at Holborn. The joint concern was called the Great Northern, Piccadilly and Brompton Railway.

The expenditure on the railway down to June 30th last was £5,738,240, and the further capital expenditure is estimated at £1,467,760, giving a total of £7,206,000—the equivalent of the authorised capital representing a capitalisation of about £800,000 per mile.

The whole Great Northern, Piccadilly and Brompton Railway undertaking is leased in perpetuity to the Underground Electric Railways Company at a yearly rent equal to interest at 4 per cent. per annum on the amount for the time being paid up on the debenture shares, and stock of the former company.

The total length of the railway, including the surface portion of the line about a mile long between West Kensington and Hammersmith which runs alongside the District Railway, is nine miles, and the spur from Holborn to the Strand

GREAT NORTHERN PICCADILLY AND BROMPTON RAILWAY.


SLEEPERS
RUNNING RAIL JOINT.
CONDUCTOR RAIL BONDING
NEGATIVE CONDUCTOR RAIL 85 LBS.
RUNNING RAIL 90 LBS.
POSITIVE CONDUCTOR RAIL
RUNNING RAIL 90 LBS.
FELT PAD ¼" THICK
CRUSHED GRANITE CUBES (WASHED) TO PASS 2½" RING
SECTION OF RAIL & FISHPLATE

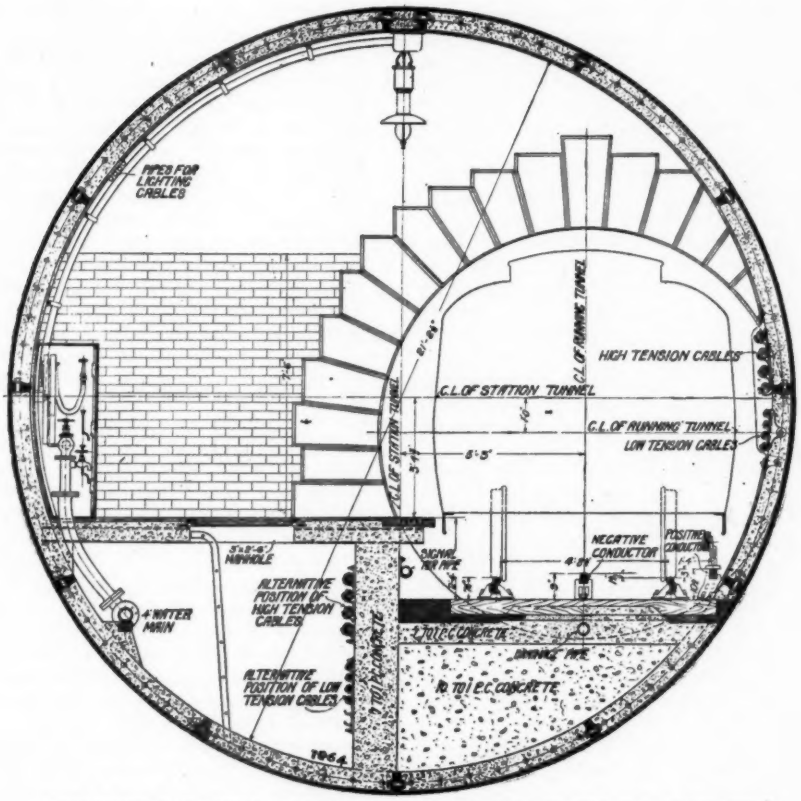
GREAT NORTHERN, PICCADILLY AND BROMPTON RAILWAY. DETAILS OF PERMANENT WAY.

accounts for an additional length of about 700 yards. The following are the passenger stations on the main line :—

Finsbury Park.	King's Cross.	Piccadilly Circus.
Gillespie Road.	Russell Square.	Dover Street.
Holloway Road.	Holborn.	Down Street.
Caledonian Road.	Covent Garden.	Hyde Park Corner.
York Road.	Leicester Square.	Sloane Street.
Brompton Road.	Gloucester Road.	Baron's Court.
South Kensington.	Earl's Court.	Hammersmith.

The two last named stations are on the surface.

Under agreement, the Great Northern Railway Company constructed the Finsbury Park Station, and leased it to the Great Northern, Piccadilly and Brompton Railway Company for 999 years, at a rent equal to 4 per cent. of



GREAT NORTHERN, PICCADILLY, AND BROMPTON RAILWAY. SECTION THROUGH TUNNEL AT STATIONS.

the cost. The former company also granted a perpetual easement for the latter company's tunnels under the Great Northern Railway from Finsbury Park to King's Cross at an annual rent of £2,500.

The work of construction has been carried out by the Underground Electric Railways Company of London, of which Mr. James R. Chapman is engineer-in-chief and general manager. Mr. H. H. Dalrymple Hay was the construction engineer for the tunnels. The original engineers were Sir J. Wolfe Barry and Partners, Mr. A. Ross, Sir James W. Szlumper, Mr. W. W. Szlumper and Mr. C. A. Brereton.

The tunnel portion of the work was divided into two sections, contracts for which were let to Messrs. Walker, Price, and Reeves, and Messrs. Walter Scott and Middleton, while Messrs. Bott and Stennet acted as contractors for the open-air portion of the line. The latter length involved some heavy work, including the widening of the district railway itself and the diversion of a considerable portion of its permanent way, and the enlargement of Hammersmith station to serve as a joint station for the two railways. Baron's Court Station being of recent construction, was planned to include joint accommodation, the work being

carried out when the widening was made. The tunnels, permanent way and line equipment are almost identical with those of the Baker Street and Waterloo Railway, already described in THE ENGINEERING REVIEW.

Typical sections of tunnel are given in the accompanying illustrations. There are two circular tunnels, one for each line of way, and each tunnel is 11 ft. 8 ins. in diameter on the straight, 12 ft. on curves of not less than 10 chains radius, and 12 ft. 6 ins. on sharper curves. The diameter of each station-tunnel is 21 ft. 2½ ins. Tunnelling operations were commenced at Sloane Street, in July, 1902, the tunnels being driven through the London clay, and lined throughout with cast-iron segments in the usual way. On the tunnel portion of the railway there are three single crossovers—viz., one at Hyde Park Corner, one at Covent Garden, and one at York Road, where enlarged tunnels had to be provided. There is also a double crossover at Finsbury Park and a turnout for the Holborn to Strand branch. On the open portion of the line there is a single crossover at Baron's Court and a double crossover at Hammersmith. Several sidings are also provided in connection with the car-sheds at Lillie Bridge. The maximum gradient is 1 in 33, and the radius of the sharpest curve is 330 ft.

The permanent way is of a type which has given every satisfaction as regards vibration on the Baker Street and Waterloo Railway, searching tests on which were carried out with instruments capable of magnifying tremors, due to the passing of trains, three hundred times. The construction consists of a foundation of concrete, which is narrower than the length of the sleepers, so that the ends of the latter, which carry the track rails, are overhung to allow a certain amount of spring. The sleepers are of Australian Karri wood (supplied by Messrs. Millar's Karri and Jarri Wood Co.) and are non-inflammable, their ordinary dimensions being 6 ft. 6 ins. by 14 ins. by 5 ins. Those which carry the insulators for the conductor rails are 6½ ins. longer. The spacing is 3 ft. 4 ins. and at joints 1 ft. 8 ins. The running rails, supplied by Messrs. Bolckow, Vaughan & Co., are of Bessemer steel, bull-headed section, weighing 90 lbs. per yard, and are laid to standard gauge. The chairs, which weigh 30 lbs. each, rest on pressed fibre pads ¼ in. thick, and they are secured to the sleepers by large thread lag screws. The screws are prevented from making metallic contact with the chairs by vulcanised fibre bushings and washers. The fishplates are of rolled steel, 1 ft. 6½ ins. long for the outside and 1 ft. 4½ ins. for the inside, and weigh 28 lbs. per pair. They are secured by $\frac{1}{16}$ in. Ibbotson's bolts. The conductor rails are of rectangular section, weighing 85 lbs. per yard, and having a resistance 6·4 times that of pure copper. These rails were also supplied by Messrs. Bolckow, Vaughan & Co. The insulators are of the Doulton type and identical with those of the Baker Street and Waterloo Railway. A different pattern is installed, however, on the open air portion of the line better capable of resisting rain. The positive conductor rail is close to the tunnel wall and the negative is midway between the running rails. Flexible plaited wire bonds are used. No longitudinal motion of the sleepers is possible as angle irons, spiked to the underside of the sleepers, are embedded in the concrete. The ballast consists of ⅜ in. granite cubes. Drainage is by cross gutters, giving access to a 3-in. drain-pipe embedded in the concrete, the water being carried to sumps at the foot of each gradient.

Very little water, however, makes its way in, as the lime grouting surrounding the iron tunnel is practically water-tight, and further, the London clay itself is impervious to moisture.

As above-mentioned, power is supplied from the power-station of the Underground Electric Railways Co. by Westinghouse turbo-generators of 5,500 kilowatts each generating three-phase, alternating current at a pressure of 11,000 volts, and with a periodicity of 33⅓ cycles per second.

Three-core insulated lead-covered cables supplied by the British Insulated and Helsby Cables, Limited, are led underground from the power-station to Earl's Court. Here the cables for the District, Baker Street and Waterloo, and Charing Cross, Euston, and Hampstead Railways are carried alongside the District Railway, while those for the Great Northern, Piccadilly and Brompton line are taken down a shaft just to the west of Earl's Court Station to the tunnels below. These cables, six in number, are 37/13 and 37/15 in gauge, are in duplicate, and are mounted on brackets on the tunnel walls. The railway also receives current through the District Railway sub-stations at Earl's Court and South Kensington.

The cables are led to sub-stations erected at Hyde Park Corner, Russell Square and Holloway, the equipment of which consists of rotary converters, transformers, high and low tension switch gear, provided by the British Westinghouse Electric and Manufacturing Co., Ltd.

The low-tension cables, which are also of the British Insulated Co.'s make, feed the conductor rails at intervals, the voltage being from 550–600. The passenger stations have been built to the designs of Mr. Leslie W. Green, and are faced with rich red glazed terra-cotta blocks. The station platforms are of granolithic, and are 350 ft. long—59 ft. longer than those on the Baker Street and Waterloo Railway.

The lift accommodation is by the Otis Elevator Co., who have installed altogether sixty lifts, the number at each station varying from two to five. They are electrically driven, and each can accommodate seventy passengers, the floor area of the cage being 150 sq. ft. The speed of travel is 350 ft. per minute, and all arrangements have been made for the comfort and safety of the passengers. The steel ropes are wound on a drum by two electric motors of 35 h.-p. each. At Finsbury Park Station four hydraulic lifts are used, each worked by three rams, with a water-pressure of 700 lbs. per sq. in. Hydraulic power had already been installed here for the adjoining lifts of the Great Northern and City Railway. The plant consists of three sets of horizontal three-throw pumps, each set driven by a 35 b.h.-p. electric motor through spur gearing; and three sets of vertical three-throw pumps, each set driven by a 39 b.h.-p. electric motor through combined worm and spur gearing. They are controlled automatically, according to the demand for power, each motor being stopped and started by a special regulating resistance switch. At Holloway Station one of the lift shafts is occupied by a novelty in the shape of double spiral continuous-moving tread, which travels at 100 ft. per minute, and can take passengers up and down simultaneously. The tread, which is experimental so far as this railway is concerned, though in use elsewhere, was supplied by the Reno Electric Stairways and Conveyors, Limited, London. All lift shafts are also provided with steel stairs. At Gillespie Road there are no lifts, as the line here is near the surface.

A very complete system of ventilation has been installed consisting of nineteen exhaust fans, by Messrs. Heenan and Froude, distributed along the line, each of which draws 18,500 cu. ft. of air per min. from the stations and tunnels. The fans are in the surface buildings, and are connected by air ducts of 16 sq. ft. cross section area with the points of suction in the tunnels. The outcast is through the roof of the building. Fresh air enters at each station by the shafts, &c., to compensate for the air extracted.

The stations are lighted by Maxim arc lamps and also by incandescent lamps, the latter being also used for lighting the tunnels throughout.

The exterior of the station buildings, booking halls and platforms are lighted by Maxim arc lamps fed from the same circuits as work the lifts, while in case of emergency they can be switched on to the conductor rails.

There are also a number of 16-candle power incandescent lamps in each station, the interior of the tunnel being also thus illuminated. The lamps in

the tunnel are spaced at 42 ft. apart and these together with the incandescent station system, are fed from a 220-volt three-phase circuit supplied from the sub-stations, through separate transformers, thus rendering them entirely independent of the traction supply. As in the case of the main lighting circuit, throw-over switches are provided whereby, should any circumstance necessitate the high tension side at one sub-station being shut down, a circuit could be established from another sub-station.

The signalling system has been carried out in the Westinghouse electro-pneumatic plan already installed on the District and Baker Street and Waterloo Railways. It comprises both automatic and semi-automatic working. The points and semi-automatic signals at interlockings are controlled from signal cabins by Westinghouse power frames. The signals for all other places are automatic and are controlled by track circuits with relays in series between the two track rails. The latter are bonded for the signalling current, and when they are short-circuited by a train on the section the signal goes to danger. When no train is on the section the relays and pneumatic signal motors hold the signal at clear. Low-pressure current for the track circuits is obtained from the sub-stations, as is also the compressed air for the pneumatic motors. The pressure between the running rails is 3½ volts, and even with this small difference careful provision has been made for insulation, even the chair bolts being fitted with fibre bushes to prevent short-circuiting. Illuminated track diagrams are installed in the signal boxes, whereby the position of every train in the vicinity can be seen, as the occupied track sections are dark, and the unoccupied are illuminated. In connection with every signal a train stop has been fitted, so that if a danger signal is overrun by a train the stop actuates an air cock on the train, thus applying the brakes.

When, on account of curvature, it is impossible to see some of the signals until the train is too near, a repeater signal lamp has been placed approximately 400 ft. in front of the signal. Oil lamps of the "Adams-Westlake" pattern are used for the signals. In the event of a failure of any part, or a loss of power, the signals to go to danger.

Mention should be made of the very elaborate system of telephones installed in connection with the railway. Every passenger station, booking office, signal box, repair shop and sub-station is provided with a telephone connected to an exchange which has been established at Leicester-square, where there is a 100-pair telephone switchboard. A pair of bare wires are also suspended along the walls of the tunnel, by means of which the driver or conductor of any train can establish communication with any part of the system with a portable instrument carried on the train.

Ample car-shed and workshop accommodation has been provided at Lillie Bridge, Brompton. The buildings are very long and narrow, the length being 1,312ft. and the breadth 78 ft. 6 ins. They are constructed of brick with steel roofs and Mellowes' glazing. There are eight tracks, besides several sidings, and they are placed over pits 4 ft 1 in. running the whole length of each track. No conductor rails are laid inside the car-shed, but an arrangement of overhead conductors is provided, consisting of a pair of rails upon which runs a small two-wheeled trolley, to which a twin flexible cable is attached. This cable can be plugged into a special socket on any train which can thus be moved. The total number of cars to be employed on the railway is 216, of which 72 are motor cars and 144 are trailers, all being of the all-steel type. The order for the vehicles was equally divided between Les Ateliers du Nord de la France, Blanc Misseron, and the Hungarian Railway Carriage Company, Raab, Hungary.

The vehicles are similar to those now in use on the Baker Street and Waterloo line; but, instead of being painted scarlet and cream externally, they are finished in engine lake. They have also been completed with a smooth external surface, no rivet-heads being visible as

is the case on the cars on the other railway. Internally they are panelled in mahogany, $\frac{1}{16}$ in. in thickness, which is mounted upon asbestos mill-board. Small as is the quantity of wood employed, it has all been rendered non-flammable by special chemical treatment. The length over-all of each car is 49ft. $1\frac{1}{2}$ in.—the height 9 ft. 4 ins., extreme width 8 ft. 4 ins. and the inside height 6 ft. $4\frac{1}{2}$ ins. The electrical equipment is on the Sprague-Thomson-Houston multiple-unit control system, supplied by the British Thomson-Houston Co. Ltd, and is practically identical with that employed on the Baker Street and Waterloo Railway. The motors are of the G. E. 69 type, rated at 200 b. h.-p. each on the usual traction rating, four of these motors being provided on each train. Both cross and longitudinal seats are employed, and each motor-car seats forty-six passengers and each trailer fifty-two. A standard train consists of six cars, including a motor-car at each end and four trailers between. Each car is lighted by thirty-five incandescent lamps.

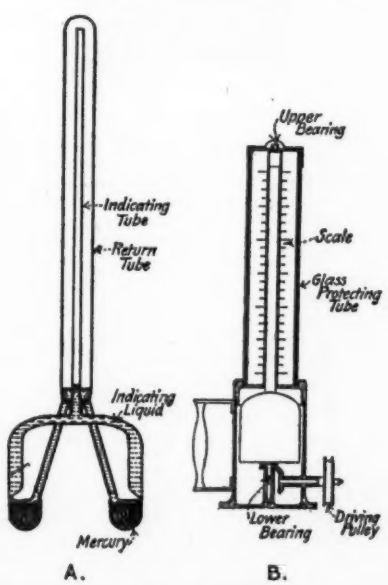
In conclusion we have to acknowledge our indebtedness to Mr. Chapman, the chief engineer of the railway, for facilities afforded us for inspecting the line and for the drawings accompanying the article.

New Machinery and Appliances.

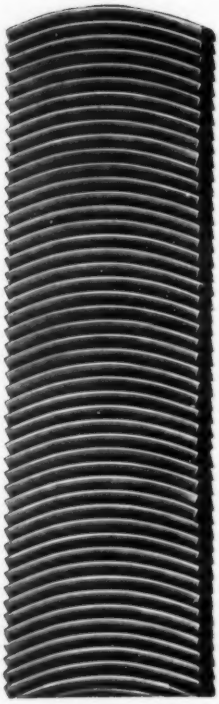
A Bi-Fluid Tachometer.

A novel type of tachometer, which depends for its action on the centrifugal effect upon a liquid contained in a rotating vessel, thereby producing a difference in level, has recently been introduced by the Niagara Tachometer Co., of Niagara Falls, New York.

The details of the apparatus are shown diagrammatically in Figs. 1 and 2, for which, as for the details, we are indebted to the *Engineering News*. Two liquids are employed, the heavier, mercury, being contained in two small closed hemispherical cups at the ends of the projecting legs. At the outer edge of the cover of each cup a small opening communicates with a riser filled with the lighter liquid, which is coloured to be better visible; the two risers join and lead to a vertical central indicating tube of small diameter. When the instrument is rotated about its vertical axis, the mercury tends to assume the paraboloidal surface of a free rotating liquid, and thereby sets up a pressure at the base of the riser tubes, proportionate to the speed of rotation. The pressure, represented by a given difference of level at a free mercury surface, requires a much higher column of the lighter indicating liquid to balance it, in proportion to the relative densities of the two liquids. Consequently, the liquid in the indicating tube rises a relatively large amount, and a scale alongside, calibrated in speeds of rotation, gives a direct reading of speed.



BI-FLUID TACHOMETER.



CIRCULAR CUT FILE.

The indicating tube is open at its upper end, and is surrounded and enclosed by a second glass tube, called the return tube. This latter is closed to the air at top and bottom, and from its lower end two small return drains lead to the mercury cups, by way of an opening at the inner edge of the cover of each cup. This arrangement is a protection against running the device at a speed exceeding its capacity; when the coloured liquid is forced above the top of the indicating tube, it overflows into the return tube and drains back to the cups.

One of the forms in which the combination of cups and tubes is mounted and arranged for convenient use as a tachometer is represented at B of Fig. 1. The lower part consists of a metal case, while the upper part is a wide glass tube surmounted by a metal cap. A step-bearing is formed in the lower part of the base-section, and a corresponding bearing in the cap; these bearings engage the spindle ends of the rotating element. The latter comprises the apparatus shown at *A*, subsequently mounted in a metal shell or carrying-frame, which encloses the cups and connecting-tubes; a spindle projects from the bottom of this shell, and another from the top of a metal cap fitted to the upper end of the return tube, which spindles engage the bearings mentioned. The lower spindle also carries a bevel gear, meshing with a bevel on a horizontal driving shaft journaled in a bearing in the lower part of the case. A band-wheel on the driving shaft affords means for coupling the instrument to any shaft whose speed it is desired to measure.

The range of the scale of this type of tachometer is about 1 : 4, *i.e.*, the maximum speed which it will indicate is about four times the minimum.

A Circular Cut File.

What is stated to be a simple and radical improvement in the manufacture of files consists in the method of circular cutting adopted by the Patent File and Tool Co., Ltd., of 8, White Street, E.C., on the files manufactured by them. The shape of the teeth and method of cutting are shown in the accompanying illustration, from which it will be seen that the teeth are semi-circular and are cut very deep. It is stated that this method of tooth formation enables the file to cut without slipping or running to the side and insures superior cutting qualities than are possessed by the ordinary file, besides retaining the cutting edge for a considerably longer period. Further, owing to the shape

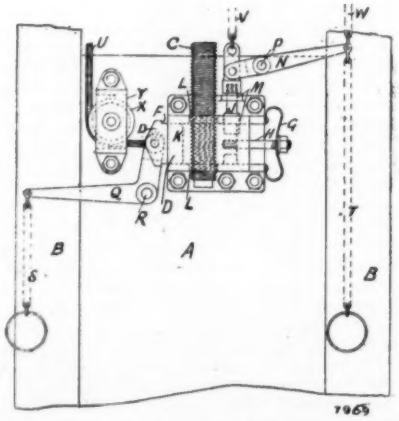


FIG. 1.—"FRANCE-STOKFLD" DOOR APPARATUS.

of the teeth, this file is said to possess self-cleaning properties, and can be used on all metals, including brass and aluminium, also for marble. The file can be recut, at very little cost, four times, whereby an economy of 36 per cent. is claimed over the ordinary file.

The "France-Stokeld" Quick Closing Door.

An interesting apparatus for quickly closing the doors of water-tight compartment bulkheads, screw alleys, caissons and coal bunkers in case of emergency was shown in actual operation at the recent Olympia Exhibition, the details of which will be readily understood by the aid of the accompanying illustrations. The apparatus has the merit of being extremely simple in its action, the only motion involved being that of raising a lock-bolt whereby a nut which engages the vertical screw by which the door is opened, is removed from contact with the screw and the door closes by its own gravity.

Referring to Fig. 1, *A* is the door, *C* the lifting screw and *D* a nut, one half of which is screwed, and the other half enlarged and not threaded to permit the requisite clearance of the screw *C* when the nut is thrown out of gear. *J* is the locking bolt, engaging the nut to which is attached the lever *N* pivoted to the door. *G* is a spring connected by the bolt *H* to the end of the nut.

The action is as follows. When it is desired to close the door the bolt is withdrawn by the lever *N* being operated either by the chain *V* or *T*, and the spring *G* immediately pulls the nut *D* out of gear with the screw *C* by withdrawing its threaded portion *E* out of engagement with the threads of the screw, thus allowing the door to fall by gravity. The speed of closing is regulated by an oil cylinder and piston as shown in Fig. 2. For putting the nut and screw into gear again the screw is lowered to the necessary extent and either the chain *S* or rope *U* are pulled, whereupon the locking bolt *J* is caused to re-engage the nut by gravity and hold it in place.

The apparatus, it will be noted, can be operated from the bridge or at the door itself. The simplicity of construction renders it suitable, not only for new doors, but for attachment, at a relatively low cost to existing vertical doors. It is manufactured by Messrs. Jas. Black & Co., Newcastle-on-Tyne.

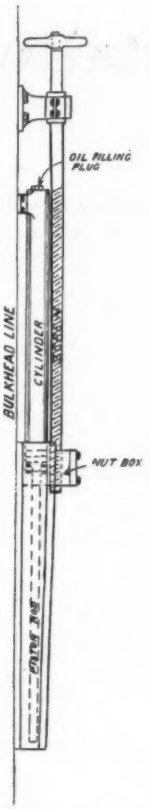


FIG. 2.—VIEW OF EDGE OF DOOR SHOWING OIL-CYLINDER AND PISTON.

Amalgamation.

An intimation is to hand to the effect that Messrs. Jessop and Appleby Bros. (Leicester and London), Ltd., have amalgamated with the Glasgow Electric Crane and Hoist Co., Ltd., under the title of Applebys, Ltd.

The London address of the new company is 56, Victoria Street, Westminster, S.W.

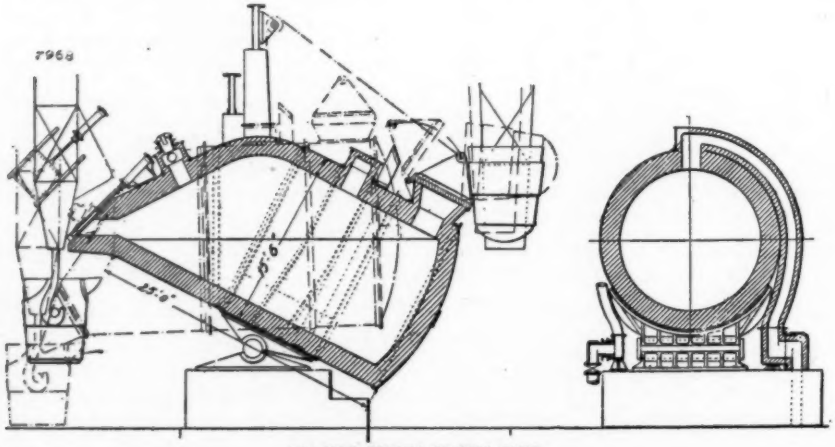
Mr. Edmund G. Appleby, late chairman of the firm of Messrs. Jessop and Appleby Bros., Ltd., is the managing director of the new concern.

Metallurgical Progress.

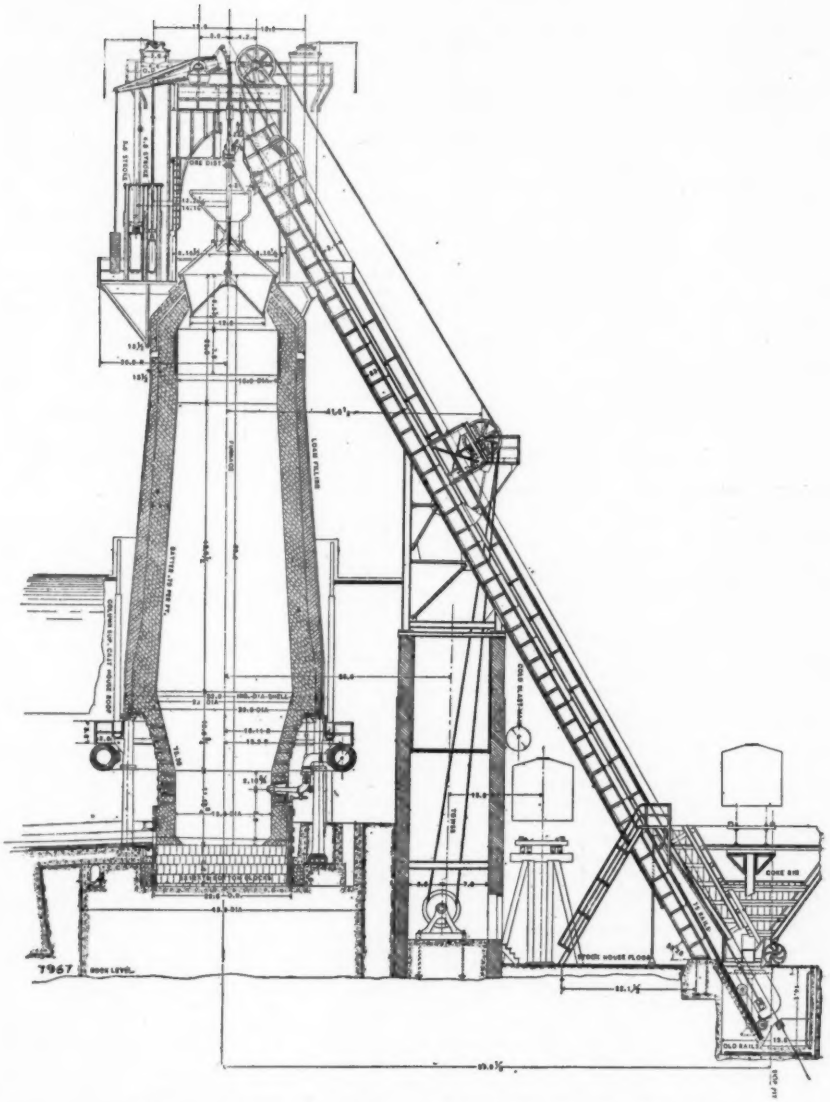
By PERCY LONGMUIR.

BLAST FURNACE PRACTICE.

New Blast Furnace.—A recent issue of *The Iron Trade Review* contains a description of new additions to the "Joliet" plant of the Illinois Steel Co., amongst which is included a 500-ton blast furnace. This furnace is 90 ft. from hearth to top, 22 ft. diameter at the bosh, and 15 ft. 6 ins. diameter at the hearth. A "Neumann" distributor is equipped, and is served by a skip hoist of the double-track deck type. The hoist is driven by two 75 h.-p. motors, either one being sufficiently powerful to operate the skip, but in service both are used, being geared to the winding drum and running considerably under load. The motors are controlled by the "Cutler-Hammer" controllers operated from the scale-house. As shown in the accompanying illustration, this furnace presents a number of unusual features, chief of which may be mentioned the arrangement of bleeders and down-comers from the top of the furnace. Instead of the down-comers being taken directly from the tunnel head, as is usual, four bleeders have been installed which rise to a height of 35 ft. from the top. The down-comers are taken off from these bleeders at right angles at a distance somewhat over 7 ft. from the top of the furnace. These lead down to a dust catcher, 25 ft. in diameter by 56 ft. high, entering the latter at a tangent. The object of this is to give the dust a whirling motion as it enters the dust catcher, and thus throw the greater quantity out by centrifugal force. The idea in installing bleeders with down-comers at a distance above the top of the furnace is that considerably less dust will be carried off in the gas than if the down-comers were taken directly from the top, especially when there is a slip in the furnace. The dust will be blown up into the bleeder, and in falling back would have to make a sharp turn to enter the down-comer. Whilst a small portion will be carried over with the gas, the greater portion of the dust will fall back into the furnace. The bells, 12 ft. and 4 ft. 3 ins. diameter respectively, are operated by two steam cylinders, controlled from the scale-house at the foot of the skip hoist. An arched structure has been erected on the furnace top, from which two girders are suspended, extending some distance outside the circumference of the top of the furnace. A trolley is suspended from these girders by means of which the bell may be removed and carried to one side whilst repairs are made to the furnace. The stock-house consists of a steel coke bin, 37 ft. by 27 ft. in length, with a limestone pocket, 90 ft. by 30 ft., between the coke bin and the furnace. Ore pockets, 120 ft. by 45 ft., are situated a short distance beyond the coke bin and under the same trestle.



GAS-FIRED TILTING PIG-IRON MIXER.



CROSS SECTION OF BLAST FURNACE, NO. 4 "JOLIET" PLANT, ILLINOIS STEEL CO.

Additional ore bins are provided under a parallel trestle. Molten metal from the furnace is run directly into ladles and carried either to "Bessemer" converters or to the pig casting machine.

Gas-Fired Tilting Pig Iron Mixers.—A series of mixers and the principles involved in their construction are given in a late issue of *The Iron and Coal Trade Review*. As a selection we give the one shown in Fig. 1, which represents a tilting mixer of 250 tons capacity heated by gas and cold air. This mixer rocks on a shaft, and is operated by hydraulic power. At the top of the vessel is the mixing chamber, to which the gas is brought by pipes attached to and oscillating with the mixer. As the pressure of the gases is insufficient to draw in enough air for combustion, air under pressure is introduced through a tuyere, the latter being arranged on the injector principle so as to draw in further air at atmospheric pressure. A cavity constructed round the vessel carries off the products of combustion to a stack.

STEEL: ITS PRODUCTION, PROPERTIES AND TREATMENT.

The Kjellin Furnace.—Mr. J. Harden, lecturing on this furnace before the Sheffield Society of Engineers and Metallurgists, made no extravagant claims on its behalf, a feature highly appreciated by the crucible steel-makers. After giving a description of the furnace and process, the speaker directed attention to useful fields in which the furnace could be profitably employed. Unfortunately, misleading statements have been published stating the "Kjellin" furnace to be capable of producing high-class crucible steel from inferior materials, and that, as a result, the coke crucible process was doomed. The "Kjellin" furnace is practically a modified crucible furnace, and high grade raw material must, as hitherto, be used for producing high-class steel. The furnace will permit of larger casts, a cheaper and cleaner form of melting and reduced labour costs. The demand for large crucible ingots is an increasing one, and the induction furnace will readily meet this demand, for in it a two-ton charge can be made as easily as a 60 lb. charge in a crucible. Taking costs, it is admitted that melting costs in the case of crucible steel are between £7 and £8 per ton. With the induction furnace one ton of steel would require from 800 to 900 units, and the costs of power would (in Sheffield) be from £2 to £2 2s. 6d. per ton. Two men and one boy would run a furnace, turning out four tons in twenty-four hours, so that the labour cost should not exceed 7s. 6d. per ton. Lining and repairs should not exceed 2s. 6d. per ton, and total melting cost would therefore be under £3 per ton.

Nickel-Silicon Steels.*—M. Guillet, following his now stereotyped plan, examines a series of alloys of varying carbon, nickel and silicon content. In all, some six series are included and a wide range in the variable element is thus offered. But we also note that the elements which should not vary do so to a very alarming extent. Thus the lowest manganese in the first series is 0·037 per cent., whilst the highest is 0·309 per cent. The same element varies in the last series from 0·043 to 0·38 per cent., whilst in the fifth series the variation is from 0·006 per cent. to 0·455 per cent. The phosphorus contents of the fifth series are truly remarkable, thus the lowest is found in 0·021 per cent.; the highest in 0·587 per cent., whilst another member of the series contains 0·450 per cent. We have on another occasion referred to the careless character of M. Guillet's proof reading and to the discrepancy between tabulated figures and diagrams plotted from those figures. If the manganese and phosphorus results as given are correct, then M. Guillet's methods of investigation are open to severe criticism, for the absurdity of studying the joint effect of two special elements in the presence of 0·587 per cent. of phosphorus is apparent to even the most elementary student.

However, taking the author's conclusions, he demonstrates that nickel,—silicon steels may be grouped according to their structure into seven classes:—

(1) Pearlitic steels.
(2) Steels simultaneously enclosing pearlite and graphite.
(3) Steels containing all the carbon in the form of graphite.
(4) Martensitic steels.
(5) Martensitic and graphite steels, which may also contain ferrite.
(6) Steels of γ iron.
(7) Steels of γ iron and graphite, which may contain at the same time ferrite and martensite.

It should be noted that in steels of γ iron, even in those which do not enclose graphite, white points are present in the structure, which may represent a silicide. From mechanical tests of the normal steels, it is shown that the pearlitic steels have a higher breaking load and limit of elasticity than is the case with simple nickel steels. At the same time elongation and resistance to shock are more feeble. The martensitic steels have a high breaking load, but are very fragile, the influence of silicon not being clearly defined. Steels of gemma iron are rather improved by the addition of silicon, which raises their breaking load. From an industrial point of view it is necessary to recall the fact that silicon raises the points of transformation of nickel steels, and that, by consequence, it changes the per centage of nickel at which the passage of one structure to another occurs, it also facilitates the transformation of γ iron into martensite. Finally,

* *Revue de Metallurgie.*

the addition of silicon to nickel steels is not advised, at least in amounts greater than 2 per cent.

Recognition of Sulphide Areas in Iron and Steel.—Baumann, in *Metallurgie*, gives the following method of locating sulphide areas:—A sheet of photographic paper, or paper moistened with bromide of silver and dilute sulphuric acid, is applied to a polished surface of the steel. After removal, those parts in contact with sulphide will be found to be coloured a deep brown.

FOUNDRY PRACTICE.

Combined Influence of Certain Elements on Cast-Iron.*—Mr. A. H. Hiorns, in an exhaustive research, presented the Staffordshire Iron and Steel Institute details of the influence of two elements when simultaneously present in highly-carburised iron. Each alloy was made to contain only two elements in addition to iron and carbon, and each may be considered as pure with regard to the specific elements introduced. Each series contains the constituents in three different proportions, so as to give each in its turn a dominant, an equal and a subordinate influence as regards the quantity present. The following percentages in the accompanying ratio were taken:—2:2, 2:1, 1:2. The method of preparation lay in melting in a carbon crucible under a charcoal covering, the alloys being maintained in a fused state for one hour in order to favour, if possible, the absorption of further carbon. The whole was then transferred to a muffle furnace and maintained at a temperature of about 1,100° C. for several hours in order to facilitate any separation of carbon in the form of graphite. Taking manganese and silicon first, it is stated that the latter element, even if it does not facilitate the separation of graphite, at any rate does not prevent such separation. On the other hand, manganese acts as a check on this separation, so that it may be safely assumed that the two elements, silicon and manganese, tend to neutralise each other, and it is only a question of the proportion of each requisite for neutralisation. The three alloys made in the proportions given, tend to prove that silicon and manganese in cast-iron neutralise each other. The experimental work gives strong presumptive evidence of the union of manganese with silicon in the proportion of 55 to 28, forming the compound $Mn\ Si$, for if a higher proportion of silicon united with the manganese there could be no free cementite which is present in two of the alloys. On the other hand, if a lower silicide were formed, the matrix of the 1 per cent. silicon alloy would not be likely to be structureless. It follows that 28 parts of silicon will neutralise 55 parts of manganese which is nearly in the proportion of 1 to 2.

Manganese and Phosphorus.—The alloy with 2 per cent. manganese and 2 per cent. phosphorus is not uniform in composition, the three chief constituents, pearlite, cementite and phosphide entectic, being irregularly distributed. In addition to these constituents there are a few small flakes of graphite running through the pearlite areas. The manganese has very largely prevented the separation of graphite, and the carbon therefore remains chiefly as cementite. The phosphorus has combined with the iron to form a phosphide which is hard, white and moderately fusible, so that it remains liquid after the general mass has solidified. The alloy containing 2 per cent. manganese and 1 per cent. phosphorus gives a structure somewhat similar to the preceding one, but the amount of phosphide entectic is less; the pearlite is also present in quantity, and the amount of cementite is more pronounced. Graphite in the form of flakes is absent. An alloy containing 1 per cent. manganese and 2 per cent. phosphorus differs considerably from the preceding, in containing a large proportion of graphite and in the absence of plates of cementite. If, according to the views held, phosphorus is neutral as regards any action on carbon, then the manganese present must tend to prevent the formation of graphite. But in the present alloy a fair proportion of graphite is in evidence, therefore 1 per cent. manganese is insufficient to prevent some graphite separating out, and this is due to the long sustained high temperature at which the alloy was kept.

Manganese and Sulphur.—Both these elements act in the same way as regards their influence on the carbon condition, and when each is separately present the carbon tends to remain in the combined form, the separation of graphite being prevented. With the simultaneous presence of manganese and sulphur, the latter combines with the manganese in preference to iron, and as manganese sulphide has a high melting and high dissociation point, the sulphur is not liberated in the gaseous form and blowholes, and red-shortness are largely prevented. Owing to the high melting point, it follows that in a cooling liquid mass of cast-iron, manganese sulphide is the first to crystallise out, leaving the iron and carbon free to assume their accustomed forms, hence the favourable action of manganese on iron containing sulphur. The hurtful influence of sulphide of iron is due to the fact that being the constituent to solidify last, it segregates between the grains, and thus breaks the continuity of the mass The alloy containing 2 per cent. manganese and 2 per cent. sulphur, consisted of sulphide of manganese, flakes of graphite, some pearlite and a little free cementite. The alloy containing 2 per cent. manganese and 1 per cent. sulphur, contains manganese in excess, but the structure is very similar to the preceding one. With 1 per cent. manganese and 2 per cent. sulphur, the alloy contains no graphite. The structure consists mainly of pearlite,

* *The Iron and Coal Trades Review.*

having well defined boundaries of cementite and some needle-shaped grains of cementite striking across the pearlite. There are also frequent blowholes, showing the influence of decomposed sulphide of iron. These alloys were made to contain the contents of sulphur mentioned, but owing to volatilisation losses, the actual figures are 1·53, 1·43 and 1·0 per cent. respectively.

Silicon and Sulphur.—The effect of sulphur is much more powerful than that of silicon, so that in these alloys very little graphite may be expected, and such is really the case. The structure is very confused, and in each case it is difficult to get more than a small area free from blowholes. In making the alloys, in each case, some of the sulphur was volatilised. The 2 per cent. sulphur, 2 per cent. silicon alloy, presented a fine structure containing pearlite, some massive cementite, patches of sulphide of iron and many blowholes. Graphite, in a very divided state, was also present. Two per cent. silicon and 1 per cent. sulphur gives a similar structure to the preceding, whilst the sample containing 1 per cent. silicon and 2 per cent. sulphur is whiter, harder and contains much more massive cementite.

Phosphorus and Silicon.—Of these two elements one can be considered neutral and the other active with regard to the separation of graphite. Hence the effect of time and temperature can come fully into play, and the carbon since it does not combine with silicon or phosphorus can separate as graphite under the right conditions of time and temperature.

Phosphorus and Sulphur.—The influence of these elements is strongly marked, and the particular structure induced by each is clearly indicated. With 2 per cent. phosphorus and 2 per cent. sulphur blowholes are plentiful, wide bands of cementite occur in all parts, and the phosphorus compound is arranged parallel with these bands. The matrix is made up of well-developed pearlite. Two per cent. phosphorus and 1 per cent. sulphur gives a similar type of structure, but with phosphide entectic in greater quantity. The alloy with 1 per cent. phosphorus and 2 per cent. sulphur has also the same general structure, but massive structureless cementite is abundant and the phosphide entectic less in quantity.

Converter Steel Castings Practice.* —In this, the second instalment of the series, Mr. A. Simonson gives details of converter linings. Generally speaking three methods may be followed, all of which are equally good, and the choice of any particular one lies in convenience and local conditions. Thus the converter may be lined with special blocks which, though expensive, reduce the time occupied for repairs. The chief drawback to the use of these special blocks is that in making repairs a large amount of good brick has often to be cut away to make room for the new block. The second method is found in ramming in a sand (ganister) lining and is probably as good and cheap as any, provided the proper grade of material is available. The third method is found in the use of ordinary form furnace brick, and this plan is probably the most widely followed. Whatever material is used it is necessary that it should be as refractory as possible, and nothing should be used in the way of brick that has been burnt at a lower temperature than is necessary to turn a 3,500° Seger cone. This means about 95 per cent. silica and almost perfect freedom from lime and magnesia. In the case of ganister mixture the very best silica clay must be used, and in order to cause it to set hard it may be mixed with weak lime water instead of ordinary water. As regards the life of a lining, definite figures can hardly be given owing to the number of variables. By making repairs at short intervals and preserving the original lines of the converter, the life of the lining will be preserved indefinitely, and the blows will be much more regular and uniform. The parts most subject to corrosion are the regions immediately surrounding the tuyeres and at the base of the upper cone where the metal lies when the converter is in the pouring position. When repairing tuyers, bars slightly less in diameter than the holes should be inserted and ganister rammed around them and allowed to dry with the bars in position. By careful attention to repairs from 150 to 200 blows may be obtained from the converter before renewing the tuyeres, and up to 1,000 blows before it is necessary to entirely reline.

Turning to the melting stock the author states that the composition of the charge must be definite within certain limits, and this necessarily involves an allowance for the changes occurring during the passage of the charge through the cupola. The analysis of the metal before blowing must be :—

Silicon	1·80 to 2·10 per cent.
Manganese	0·60 to 1·00 "
Sulphur and phosphorus	as low as possible.
Carbon	about 3 per cent.

The cupola charges are made up of pig iron and steel scrap, the latter being obtained in the form of heads, runners and wasters from previous heats. The flux used is limestone or oyster shells and the coke is seventy two coke with a sulphur content in the neighbourhood of 0·75 per cent. In calculating the cupola charge the two elements closely controlled are silicon and manganese. Carbon, that is total carbon, is practically the same in all grades of pig iron used, and the relation of combined carbon to graphitic carbon is immaterial, for after the first few minutes blowing all the carbon will be in the combined state. Familiar methods of calculating charges according to silicon and manganese contents are given.

* *The Foundry.*

Cracks in Open Hearth Steel Castings.—Mr. W. M. Carr, in the *Iron Trade Review*, gives as one prominent cause of cracking red shortness in the metal. If cracks are numerous the cause is mainly due to the character of the flame in melting and the method of refining. Under such conditions the metal becomes contaminated with an oxide of iron that acts in a measure precisely the same as sulphur is said to do, further, whilst it is possible to deoxidise such metal to the extent that blow-holes caused by gaseous steel are absent, yet red shortness will still be present. Many instances have been observed which point to the fact that there must be an indefinable oxide of iron which does not submit to the cleansing action of silicon and manganese as final additions. The remedy lies in correct furnace manipulation and a careful working down of the charge will retard the absorption of this oxide and at the same time eliminate cracks due to red shortness. However, in addition to red shortness, the resistance offered by the mould and the design of the pattern have a decisive effect on the development, or otherwise of cracks in the casting. The conditions of crumbling at a high heat are peculiar to all carbon steels, and even in the entire absence of oxide the steel will crack if rigidly held whilst cooling and contracting.

Influence of Foreign Elements on the Separation of Graphite.—Professor Wüst, in *Metallurgie* verifies the fact that sulphur lowers the saturation point of cast iron for carbon. The action of sulphur opposes that of silicon on the separation of graphite and the quantity of graphite diminishes as the content of sulphur increases. Experiments with phosphorus have shown that in the absence of silicon the phosphorus is without influence on the formation of graphite if its content does not exceed 2·5 per cent.

GENERAL METALLURGY.

Volatilisation of Oxide of Zinc at High Temperatures.— Earlier workers have found that oxide of zinc volatilises rapidly 1,065° C., but Messrs. Doeltz and Graumann have not obtained results in concordance with these views. The experiments recorded in *Metallurgie* were conducted at temperatures between 1,000° C. and 1,400° C., and the results are of the following order: At 1,000° C. the loss varied from 0·05 to 0·09 per cent. Tests at the same temperature conducted in air passed through potash and concentrated sulphuric acid gave a volatilisation loss of only 0·012 per cent. At 1,100° C. the loss was from 0·100 per cent. to 0·101 per cent. Tests at 1,200° C. gave a loss of from 0·14 to 0·18 per cent., whilst at 1,300° C. the loss varied from 0·23 to 1·6 per cent. At 1,400° C. tests in a pure atmosphere showed a loss at the end of one hour and forty minutes of 11 per cent., and at the end of two hours a loss of 13 per cent. Trials made in an electric furnace showed that after 1,400° C. the volatilisation increased rapidly

Volatilisation of Oxide of Lead at High Temperatures.—Messrs. Doeltz and Graumann in a later issue of *Metallurgie* give a similar series of tests to the foregoing conducted on oxide of lead. After a period of one hour's heating the losses at different temperatures are as follows:

Temperature.	Loss per cent.
700° C	0·1
800° C	0·2
900° C	2·0
950° C	5·0
1,000° C	10·0

The oxide was melted at about 900° C.

Magnesium as a Deoxidiser.—Mr. P. M. Bosch, writing in the *Metal Industry*, advocates the use of magnesium as a deoxidiser in the production of alloys. Magnesium is preferably alloyed with copper, zinc, aluminium, nickel or tin, according to the character of the alloys produced. The alloy so made is added to the crucible after it has been drawn from the fire.

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The Regulation of High-Pressure Water Wheels for Power Transmission Plants. By G. J. Henry.

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Olympia Engineering and Machinery Exhibition, Sept. 19th to Oct. 19th, 1907.

The arrangements for this exhibition are being rapidly pushed forward, and the mangers have been fortunate enough to secure Lord Armstrong, Lord Kelvin, and numerous other influential engineering authorities as patrons; and on the Honorary Advisory Council such well-known men as W. Beardmore, of Glasgow; D. Donald, of Glasgow; Ernest Samuelson, of Banbury; Mr. W. Crosby, of Messrs. Edgar Allen & Co., Limited, Sheffield; and the Hon. C. A. Parsons.

It is confidently expected that this exhibition will be very much larger than the one held in 1906. Important engineers in all branches of engineering are making enquiries with regard to it.